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ART. XII.—*Contributions to Meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Twelfth paper, with three plates.

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Mean pressure of the Atmosphere over the United States at different seasons of the year.

DURING the last three or four years I have devoted much time to the study of atmospheric disturbances in their progress across the Rocky Mountains. This work has been attended with serious difficulties, a part of which have resulted from the mode in which the barometric observations at the mountain stations of the United States Signal Service are reduced to the level of the sea. The method of reduction consists in adding a constant quantity to the observations at each station; and the same constant is adhered to throughout the entire year. That this mode of reduction is erroneous appears from a comparison of the observations on Mt. Washington with the observations at neighboring stations near the level of the sea. In the following table, column 2d shows the mean height of the barometer on Mt. Washington (reduced to sea-level by the Signal Service method) for each month of the year according to the observations of six years (1871–7). Column 3d shows the mean of the observations at Burlington, Vt., and Portland, Me. (also reduced to sea-level) for the same period; and column 4th

shows the differences between the numbers in the two preceding columns.

	Mt. W.	Bur. & Port.	Diff.		Mt. W,	Bur. & Port.	Diff.
January	29·724	30·054	−0·330	July	30·225	29·929	+0·296
February	·693	29·984	− ·291	August	·282	30·008	+ ·274
March	·715	·927	− ·212	September	·165	·003	+ ·162
April	·873	·930	− ·057	October	·015	29·996	+ ·019
May	30·039	·935	+ ·104	November	29·836	·979	− ·143
June	·153	·926	+ ·227	December	·695	30·004	− ·309

We thus find that by employing a constant reduction to sea-level for all months of the year, the pressure for Mt. Washington in January is made 0·33 inch too small; and the pressure in July is made 0·296 inch too great.

A similar error must exist in the reduction of the observations at the Rocky Mountain stations, but it is more difficult to determine its exact amount, because the nearest stations of comparison which are situated less than 1,000 feet above the level of the sea, are distant over 500 miles. Under these circumstances I have endeavored to reduce the observations at each of the mountain stations to the level of the sea, for each month of the year, independently. The chief difficulty in making this reduction arises from the uncertainty as to what should be regarded as the temperature of the point situated at the level of the sea and directly under a given mountain station. The following is the method which I attempted to employ. I determined for each month the mean temperature of a point on the Pacific coast, and also the temperature of a point in the Mississippi Valley, each having the same latitude as the given station. Between the two temperatures thus determined, I interpolated a value corresponding to the differences of longitude between the given station and the two points above named.

The following table shows the required data for the month of January and the results of the computation for each of the stations (except Mt. Washington and Pike's Peak) for which the reduction to sea-level by the Signal Service is made by the addition of a constant quantity.

Stations.	Lat.	Long.	Elev., feet.	Temperature.		Reduc. to s. lev.		Mean barom.	
				Station.	Base.	Sig. S. inch.	Comp. inch.	Sig. S. inch.	Comp. inch.
Santa Fé	35° 41′	106° 10′	6862	29°·76	46°·32	6·54	6·81	29·733	30·00
Denver	39 45	105 4	5162	26·14	36·23	5·22	5·37	29·944	30·09
Cheyenne	41 12	104 42	6057	23·26	31·80	5·94	6·26	29·850	30·17
Salt Lake C.	41 10	112 0	4362	29·23	37·62	4·33	4·61	29·959	30·24
Corinne	41 30	112 18	4249	28·30	37·29	4·25	4·53	30·115	30·39
Virginia C.	45 20	112 3	5480	16·82	27·21	5·48	5·76	29·646	29·93
Fort Benton	47 52	110 40	2674	8·28	19·20	2·90	3·04	30·008	30·15

Columns 2 and 3 show the latitude and longitude of the stations named in column 1; column 4th shows the elevation of the stations above sea-level as assumed by the Signal Service; column 5th shows the mean temperature of each station for the month of January according to the observations of five years; column 6th shows the temperature at the level of the sea directly under each station, estimated in the manner already described; column 7th shows the reduction to sea-level adopted by the Signal Service; column 8th shows the reduction to sea-level computed by Dunwoody's Tables contained in the Annual Report of the Signal Service for 1876, pp. 354–360; column 9th shows the mean pressure for each station as deduced from the Signal Service observations, and column 10th shows the mean pressures corrected by the reductions given in column 8th.

If now we attempt to represent by isobaric lines all the observations at the Signal Service stations for the month of January (employing for the Mountain stations the values given in column 10 of the preceding table), we find that nearly all the observations can be well represented by curve lines which have a tolerably symmetrical form. There are only four cases in which the discrepancies amount to as much as 0·05 inch, viz: Virginia City, Santa Fé, North Platte and Dodge City.

The result above found for Virginia City indicates a probable error in the assumed elevation of that station. According to Hayden, the height of Virginia City is 5,824 feet; according to DeLacy it is 5,778 feet; and according to the Signal Service it is 5,480 feet. The mean of these three determinations is 5,694 feet. Assuming this to be the true elevation, the corrected pressure becomes 30·15, which accords pretty well with the observations at the other stations.

According to Wheeler the height of Santa Fé is 7,047 feet, and according to the Signal Service 6,862 feet. Assuming the true elevation to be 7,000 feet, the corrected pressure becomes 30·14, which accords tolerably well with the observations at the other stations.

The results at North Platte and Dodge City appear to be about 0·25 inch too small. These discrepancies cannot reasonably be ascribed to error in the assumed elevations, but they are apparently due to an erroneous mode of reducing the observations to sea-level. If the observations at these stations as published in the International Bulletin are reduced to sea-level by Dunwoody's Tables, the results will be found to agree pretty well with those at the neighboring stations. I then drew the isobars which best represent all the Signal Service observations for the month of January, including the four stations above named, with the corrections which have been indicated. These curves exhibit an area of high pressure for the central part of

the American Continent somewhat similar to that which prevails in winter over nearly the whole of Asia, but much inferior in amount. This area is however apparently divided into three subordinate areas of maximum pressure, one having its center near Salt Lake City; another near Yankton, and a third near Atlanta in Georgia.

I next made a similar comparison of the barometric observations for the month of July, and the results for the mountain stations are exhibited in the following table.

Stations.	Temperature.		Reduc. to s. lev.		Mean barom.	
	Station.	Base.	Sig. S. inch.	Comp. inch.	Sig. S. inch.	Comp. inch.
Santa Fé	69°·13	70°·31	6·54	6·35	29·898	29·71
Denver	73·00	70·24	5·22	4·92	30·105	29·80
Cheyenne	69·45	70·34	5·94	5·71	30·098	29·87
Salt Lake City	76·60	67·24	4·33	4·22	29·978	29·87
Corinne	76·20	67·19	4·25	4·13	30·028	29·91
Virginia City	65·33	69·67	5·48	5·20	29·822	29·54
Fort Benton	73·47	65·33	2·90	2·66	29·965	29·72

Column 2d shows the mean temperature of each station for the month of July according to the observations of five years; column 3d shows the temperature at the level of the sea directly under each station, estimated in the manner before indicated; column 4th shows the reduction to sea-level adopted by the Signal Service; column 5th shows the reduction to sea-level computed by Dunwoody's Tables; column 6th shows the mean pressure for each station according to the Signal Service observations; and column 7th shows the mean pressure corrected by the reduction given in column 5th.

It will be noticed that in four of the seven cases in the preceding table the temperatures in column 2d are greater than in column 3d, and the average of the temperatures in column 2d is considerably greater than in column 3d. This may be regarded as demonstrating that I have adopted a very absurd mode of deducing the temperature at the level of the sea. But it may be replied that the summer temperature in the Salt Lake Basin is higher than it is upon the same parallel on the Atlantic coast or the Mississippi river, and very much higher than it is on the Pacific coast. If we assume a decrease of temperature of one degree for each 300 feet elevation, we shall have a mean temperature of 91° for July at the level of the sea under Salt Lake City, which certainly is not the temperature which would prevail there if the mountains were removed. If we assume the temperature at the sea-level to be the same as that actually observed at Salt Lake City, the reduction of the barometer to sea-level will be 0·04 inch less

than that given in the above table, which change would not materially affect the conclusions which I have drawn from the observations.

If now we attempt to represent by isobaric lines all the observations at the Signal Service stations for the month of July (employing for the mountain stations the values given in the last column of the preceding table), we find that all the observations are pretty well represented except those at the four stations above named, viz: Virginia City, Santa Fé, North Platte and Dodge City.

If we assume the height of Virginia City above sea-level to be 5,694 feet, the corrected pressure becomes 29·74, which accords very well with the observations at the other stations. If we assume the height of Santa Fé above sea-level to be 7,000 feet, the corrected pressure becomes 29·84, which also accords very well with the other observations.

The results at North Platte and Dodge City appear to be about 0·30 inch too small, which is apparently due to an erroneous mode of reducing the observations to sea-level, as intimated on page 91.

I then drew the isobars which best represent all the Signal Service observations for the month of July, including the four stations above named with the corrections which have been indicated. These curves exhibit an area of low pressure for the central part of the American continent similar to that which prevails in summer over nearly the whole of Asia, but far inferior in amount.

The preceding part of this article was written before I had seen a copy of the Annual Report of the United States Signal Service for 1878. This report contains (pp. 418–19) the mean height of the barometer for each station from the opening of the station to June 30, 1877, the observations being corrected for temperature and instrumental error only. As soon as I saw this table I decided to substitute it for the table which I had previously prepared, and proceeded to reduce all the observations to the level of the sea in the following manner. The heights of the stations were assumed as given in the Signal Service Report for 1878 with the exception of Virginia City and Santa Fé. The height of the former was assumed to be 5,694 feet, and the latter 7,000 feet, for the reasons stated on page 91. For the month of July the temperature at sea-level was assumed to be the same as at the station. The same rule was adopted for January for stations whose altitude is less than 1,200 feet. For stations whose altitude is greater than 1,200 feet, the temperature at sea-level was determined in the manner described on page 90. The reduction to sea-level was then computed from the data thus furnished by using Dun-

woody's Tables (Report 1876, pp. 354–360), and for stations whose altitude exceeds 1,200 feet, the reduction was also determined by my tables contained in Guyot's collection of Hypsometrical Tables as published by the Smithsonian Institution, pp. 52–3. The observations at Mt. Washington and Pike's Peak, have not been employed in these comparisons.

The following table shows the data for the month of January. Column 5th shows the mean height of the barometer as determined at each of the stations; column 6th shows the mean temperature of each station and differs slightly from the numbers given on page 90, as it includes the observations of an additional year; column 7th shows the estimated temperature at the level of the sea directly under each station, and differs

January observations.

Stations.	Lat.	Long.	Altitude.	Mean barom.	Temperature.		Reduc. barom.		Diff.
					Station.	Sea lev.	Dunwoody.	Loomis.	
Santa Fé	35°·7	106°·2	7000	23·196	28°·4	46°·2	·189	·198	—·009
Dodge City	37·6	100·1	2486	27·454	26·1	39·3	·176	·181	—·005
Denver	39·7	105·1	5269	24·721	26·1	36·5	·211	·234	—·023
N. Platte	41·1	100·9	2838	27·093	18·3	30·0	·249	·255	—·006
Cheyenne	41·2	104·7	6057	23·922	23·6	32·3	·185	·193	—·008
Salt Lake C.	41·2	112·0	4362	25·660	29·1	38·1	·271	·288	—·017
Yankton	42·7	97·5	1275	28·809	11·8	24·3	·288	·290	—·002
Virginia C.	45·3	112·0	5694	24·168	17·9	29·1	·135	·159	—·024
Bismark	46·8	100·6	1706	28·228	5·7	18·0	·214	·216	—·002

somewhat from the numbers given on page 90 for the reason just stated; column 8th shows the height of the barometer reduced to sea-level by Dunwoody's Tables (30 inches being omitted); column 9th shows the height of the barometer reduced by Loomis' Table, and column 10th shows the differences between the numbers in the two preceding columns. It will be perceived that these differences are small, showing that Dunwoody's Tables accord very well with Laplace's formula.

Plate II shows the isobars drawn to represent the preceding observations and also those at the other stations of the Signal Service, together with a few observations beyond the limits of the United States contained in Buchan's paper on the mean pressure of the atmosphere (Ed. Trans., vol. xxv, pp. 575–637). These curves bear a pretty close resemblance to those derived from my first collection of observations. There is a similar area of maximum pressure having its center near Salt Lake City; there is an area of maximum pressure whose center is near Yankton, and there is an area of maximum spread out over the Southern States. In the latter area, the isobar of 30·2 inches extends further to the northeast than was previously

found, but the general features of the curves are but little changed. The breaking up of the area of high pressure into three subordinate areas is distinctly indicated, and it is scarcely to be expected that this feature will be made to disappear by a longer continuance of the observations. It appears probable that there is a permanent cause for this peculiarity, and it may perhaps be ascribed to the usual course pursued by barometric minima. The centers of great storms, particularly in winter, generally follow the eastern slope of the Rocky Mountains until they reach latitude 40° or a little further south, after which they turn eastward and soon incline somewhat to the north of east. This low barometer is partly compensated by the high pressure which succeeds it, but this compensation is apparently not quite complete.

The following table shows the data for the month of July for the same stations named in the table on page 94, and the arrangement of the table is the same.

July observations.

Stations.	Altitude.	Mean barom.	Thermom.	Reduc. barom.		Diff.
				Dunwoody.	Loomis.	
Santa Fé	7000	23·353	69°02	29·863	29·884	—·021
Dodge City	2486	27·403	77·53	·859	·869	—·010
Denver	5269	24·873	73·16	·884	·902	—·018
North Platte	2838	27·065	74·77	·872	·879	—·007
Cheyenne	6057	24·143	69·60	·854	·883	—·029
Salt Lake City	4362	25·628	76·84	·798	·816	—·018
Yankton	1275	28·674	74·18	·974	·979	—·005
Virginia City	5694	24·339	64·54	·788	·809	—·021
Bismark	1706	28·143	70·17	·880	·884	—·004

It will be noticed that the differences between the results by Dunwoody's Tables and my own are quite small, showing that Dunwoody's Tables give very good results for altitudes as great as 7,000 feet, for summer as well as winter.

Plate III shows the isobars drawn to represent the preceding observations as well as those at other stations of the Signal Service. These curves bear a close resemblance to those derived from my first collection of observations. The area of minimum pressure extends from Salt Lake City northward, and the pressure increases on each side of this area, but most rapidly on the west side. These curves generally represent the observations very well; but there are some exceptions, particularly at the stations between the Rocky Mountains and Lake Michigan. The greatest discrepancy is at Yankton, where the observed height exceeds that shown on the chart by 0·07 inch; while at Chicago the observed height is less than the chart by

0·05 inch. The observations make the pressure at Dodge City 0·03 inch less than at Denver, while the chart makes the former 0·025 inch greater than the latter. A part of these discrepancies may be ascribed to the fact that the observations at the different stations were not all made on the same years. According to the Dakota Southern Railroad Survey the elevation of Yankton is 1,202 feet. If we adopt this value, both the January and July observations at Yankton accord pretty well with the observations at neighboring stations. The observations at Chicago seem to indicate a small zero error in the barometer.

The pressure at Salt Lake City reduced to sea level appears to be 0·472 inch greater in winter than in summer; while in Central Asia the difference between winter and summer amounts to an entire inch. It is evident that the same cause operates in North America as in Asia, but with diminished energy.

Comparison of barometric minima in Europe and America.

The monthly Review of the weather for 1877 published by Dr. Neumayer of Hamburg, contains a summary of the results derived from the observations of 1876 and 1877. I propose to compare some of these results with those obtained in the United States.

Rate of progress of barometric minima.—Dr. Neumayer has given for each month of the years 1876 and 1877 the average daily progress of barometric minima in Europe expressed in myriameters. I have reduced these values to English miles per hour, and the results are shown in column 4th of the following table. For the purpose of comparison, I have placed in column 2nd the velocities deduced from three years observations in the United States as published in this Journal, vol. x, p. 1. I have also reduced to a tabular form the velocities given in the monthly Reports of the Signal Service since Nov. 1875,

	Loomis.	Sig. Ser.	Europe.		Loomis.	Sig. Ser.	Europe.
January	26·7	33·3	15·8	July	24·9	27·6	14·7
February	32·0	28·5	14·0	August	18·4	22·8	14·5
March	30·5	30·2	18·2	September	22·9	21·5	15·0
April	27·5	24·1	14·9	October	25·8	21·4	19·7
May	23·5	23·6	12·7	November	29·0	25·5	15·8
June	21·6	23·6	14·5	December	29·3	34·0	15·8
				Year	26·0	26·3	15·5

and have determined the averages for each month. These results are shown in column 3d of the table. They are derived from forty-four months of observation, and refer to the region between the Atlantic Ocean and the meridian of 100° from Greenwich.

The average velocity of storm centers as shown by the monthly Reports of the Signal Service is almost identical with that which I had previously deduced. As these two results are based on the observations of six and two-thirds years, it is probable that they will not be greatly changed by a longer continuance of the observations. Dr. Neumayer's result is deduced from observations of two years, extending over every part of Europe, and is probably a close approximation to the average velocity of storm centers in that country. The average velocity of storm centers in the United States is seen to be 69 per cent greater than it is in Europe. In my tenth paper (this Journ., vol. xvii, p. 3) I determined the average velocity of storm centers on the Atlantic Ocean to be 14 miles per hour, which is somewhat less than the value above found for the continent of Europe.

It appears then to be an established fact that storms travel more rapidly over the eastern portion of the United States than they do over the Atlantic Ocean or the continent of Europe. What cause can be assigned for this inequality? The winds on the Atlantic Ocean are certainly stronger than they are over either of the continents, and it is believed that the winds of Central Europe are generally stronger than the winds of the United States. In my eighth paper (this Journ., vol. xv, p. 16) I gave the results of an extended comparison of the winds at the Signal Service stations. For the stations north of latitude 40° (omitting Mt. Washington and Pike's Peak) the average velocity is 8·7 miles per hour. The average velocity which I have deduced from a considerable number of stations in England and its vicinity is 11·3 miles per hour. The average velocity at several stations in Northern Prussia is 11·8 miles per hour, and the average velocity at Vienna is 11·5 miles per hour. In my first paper (this Journ., vol. viii, p. 7) from a comparison of a large number of cases, I showed that generally the stronger the wind on the west side of a storm, the less the velocity of the storm's progress. If the more rapid progress of storm centers in the United States results from a difference in the velocity of the winds, it seems probable that the effect is produced by means of the vapor which is precipitated. From the Rocky Mountains to the Atlantic Ocean storms advance from a dryer to a more humid atmosphere. In Europe, while storms travel eastward, they advance from a humid to a dryer atmosphere. Upon the Atlantic Ocean the vapor on the western side of storm centers generally has a greater tension than it has upon the eastern side, owing to the warm water of the Gulf Stream. In my eighth paper (this Journ., vol. xv, p. 11) I have shown that in the vicinity of Newfoundland storms are frequently delayed several days, and this result is apparently

due to the abundant precipitation of vapor in that region. In my first paper (this Journ., vol. viii, p. 6) I have shown that when a storm center advances eastward most rapidly, the rain-area generally extends to an unusual distance on the east side; and the storm center advances less rapidly than usual when the rain-area extends but little on the east side. These facts seem to indicate that in Europe the center of the rain-area must precede the center of least pressure by a less distance than it does in the United States. I have endeavored to decide this question by a comparison of observations. The most satisfactory course would probably be to determine the position of the rain-center with reference to the point of least pressure, for a large number of cases in Europe and America; but unless we take all the storms of a year indiscriminately, we might be charged with having selected cases for the purpose of establishing a preconceived hypothesis. I have therefore adopted a different method, and have taken all those stations both in Europe and in the United States for which I could obtain a record of the rain-fall, as well as of the barometer, more than three times a day. I then divided the rain of each month into two portions, one containing the rain which fell while the barometer was descending, and the other containing the rain which fell while the barometer was ascending. Whenever it happened that the barometer remained stationary during the interval between two observations, the rain for that period was divided equally between the two columns. The materials which I have been able to obtain for this comparison are the following:

1. Observations made at Girard College, Philadelphia, from 1840 to 1845. For three years the observations were made hourly and for the other year once in two hours. 2. Hourly observations at Valencia, Armagh, Glasgow, Aberdeen, Falmouth, Stonyhurst and Kew for 1874. 3. Observations eight times a day at Paris for 1877. 4. Observations once in two hours at Brussels for six months of 1879. 5. Hourly observations at Prague for 1865, '66 and '69. 6. Hourly observations at Vienna for 1854, '55 and '56. These are all the stations in Europe and America for which I have been able to obtain observations of the rain-fall and barometer more frequently than three times a day. The results are shown in the following table, and are all expressed in English inches. When the observations at any station were continued more than one year, the average fall for all the years has been taken. The first column under each station shows the monthly fall of rain while the barometer was descending, and the second column shows the fall of rain while the barometer was rising. At the bottom of the table is shown the total fall for the year, and the last line shows the ratio of the total numbers in the two columns.

We see that at Philadelphia the amount of rain which falls while the barometer is descending, is nearly three times as great as that which falls while the barometer is rising, and during the six colder months of the year the rain-fall in the former

Relation of rain-fall to barometric pressure.

	Philadelphia four years.		Valencia one year.		Armagh one year.		Falmouth one year.		Glasgow one year.		Stonyhurst one year.	
	Fall.	Ris'g	Fall.	Ris'g	Fall.	Ris'g	Fall.	Ris'g	Fall.	Ris'g	Fall.	Ris'g
Jan.	2·36	0·42	2·90	2·04	1·46	0·49	3·52	2·92	2·13	1·18	3·38	1·54
Feb.	1·20	0·29	3·62	1·46	1·64	·31	2·95	·85	·53	·28	1·11	·63
March	2·06	0·33	1·65	1·01	1·08	·49	·89	·76	2·24	·70	5·26	·95
April	2·34	0·97	2·64	1·31	·88	·70	1·83	·83	1·02	·72	1·15	·49
May	1·95	0·58	·60	·44	·91	·18	1·05	·21	1·99	·50	·65	·98
June	2·22	0·58	·93	·53	·46	·37	1·85	·87	·63	·15	1·16	·35
July	2·03	2·63	3·31	1·65	·22	·70	1·15	·56	2·69	·99	1·97	1·07
Aug.	3·98	1·39	4·03	1·27	2·05	1·75	2·93	·67	3·14	1·24	3·95	3·07
Sept.	1·67	0·50	4·14	2·23	1·96	1·20	4·04	1·96	2·50	1·50	3·38	2·09
Oct.	1·43	0·52	5·28	1·96	2·60	1·04	5·01	1·60	5·57	1·62	3·69	2·95
Nov.	2·60	0·48	3·45	1·08	2·12	·76	3·84	·76	2·61	1·15	3·19	1·40
Dec.	3·19	0·68	5·17	2·06	1·91	·91	6·44	2·66	1·66	·41	2·81	·85
Year	27·03	9·37	37·72	17·04	17·29	8·90	35·50	14·65	26·71	10·44	31·70	16·37
Ratio	2·88		2·21		1·94		2·42		2·56		1·94	

	Aberdeen one year.		Kew one year.		Paris one year.		Brussels six months.		Prague three years.		Vienna three years.	
	Fall.	Ris'g	Fall.	Ris'g	Fall.	Ris'g	Fall.	Ris'g	Fall.	Ris'g	Fall.	Ris'g
Jan.	1·04	0·27	0·53	0·43	1·55	0·56			0·30	0·27	0·88	0·42
Feb.	1·25	·43	·82	·29	·55	·37	1·59	1·56	·78	·46	·57	·58
March	·65	1·97	·22	·21	·51	·15	·30	·50	·80	·86	·12	·22
April	·55	·53	1·04	·22	·83	1·45	1·52	·90	·31	·55	·08	·32
May	·75	·64	·33	·27	0	0	·76	·53	·47	·76	1·13	1·02
June	1·00	·12	1·55	·99	2·58	1·94	1·02	2·79	1·00	1·34	1·04	1·09
July	1·18	1·16	·88	·39	1·68	1·07	1·93	2·82	·63	1·41	·42	2·26
Aug.	3·99	2·69	1·04	·24	·64	·64			·60	1·16	1·10	1·45
Sept.	1·23	·96	2·07	·73	1·61	·47			·10	·52	·47	1·02
Oct.	1·23	1·06	2·00	1·72	·71	·87			·10	·48	·49	·42
Nov.	2·35	1·36	1·52	·62	·28	·09			·76	·53	1·30	·52
Dec.	·90	2·03	1·12	·42	·59	·15			·57	·41	·73	·35
Year	16·12	13·22	13·12	6·53	11·53	7·76	7·12	9·10	6·42	8·75	8·33	9·67
Ratio	1·22		2·01		1·49		0·78		0·73		0·86	

case is nearly five times as great as in the latter case. In summer there frequently occurs a thunder shower with an excessive fall of rain accompanied by a slight rise of the barometer, and this affords the explanation of the fact that in July more rain occurs with a rising than with a falling barometer.

At the stations near the west coast of Great Britain and Ireland, the amount of rain with a falling barometer is more than twice that with a rising barometer; but this ratio rapidly dimin-

ishes as we advance eastward. At Paris this ratio is reduced to one and a half; and in Central Europe more rain falls while the barometer is ascending than while it is descending.

From these observations we must conclude that storms may travel eastward even though the center of the rain-area is somewhat west of the center of low pressure. In my tenth paper (this Journ., vol. xvii, p. 12) I have shown that the change of wind which accompanies a barometric minimum generally begins at the surface of the earth, before it does at elevated stations, indicating that the west wind in the rear of the storm pushes under the east wind, lifting it from the surface of the earth, so that a change of wind and an increase of barometric pressure is observed at the surface before there is any change of wind at the elevation of 2,000 or 3,000 feet. This movement of the winds does not prevent the storm center from advancing eastward, but the storm advances less rapidly than when the center of the rain-fall is considerably east of the center of low pressure, as is generally the case in the United States.

Barometric minima advancing with unusual velocity.

Dr. Neumayer finds in Europe occasional examples of barometric minima which remain nearly stationary for a few days; and there are other examples of minima which advance with extreme rapidity.

On the 9th of September, 1876, there was a barometric minimum (29·06 inches) not far from Königsberg in Prussia. Thence it made a circuit through the southern part of Sweden and Norway, and at the end of six days it was in Holland about 720 miles west of the first named position. On the 19th of December, 1876, there was a barometric minimum (28·70 inches) near the southern extremity of Ireland. Thence it made a circuit through England and back into Ireland, and at the end of six days was near Cherburg in France, less than 500 miles distant from the point first mentioned.

The following table shows all the cases in 1876 and 1877 in which storm centers advanced over 1000 miles in twenty-four hours.

Column 3d shows the progress of the barometric minimum in twenty-four hours expressed in English miles; column 4th shows the height of the barometer (in English inches) at the center of the storm at the beginning of the day in question; column 5th shows the latitude of the center at the beginning of the given day; column 6th shows the height of the barometer at the center of the storm at the end of the given day; column 7th shows the latitude of the center at that instant; column 8th shows the force of the strongest wind reported at any station for that day. The scale is not

stated but is supposed to be 1 to 12. Column 9th shows the different directions of the winds whose force is given in the preceding column.

No.	Date.	Progress, miles.	Barom. Eng. inch.	Lat.	Barom. Eng. inch.	Lat.	Wind.	Direction.
	1876.							
1	Aug. 25–26	1000	29·37	43°8	29·29	57°3	8	N.; W.; S.W.; S.E.
2	Oct. 10–11	1330	29·13	57·0	29·21	56·0	10	W.S.W.; S.W.
3	Oct. 12–13	1094	28·66	62·2	28·74	68·0	10	W.N.W.; S.W.; S.S.W.
4	Oct. 14–15	1131	29·25	63·2	29·45	65·0		
5	Dec. 2– 3	1031	29·13	54·0	29·13	54·0	10	S.S.W.; E.S.E.; E.
6	Dec. 5– 6	1174	28·35	51·8	28·35	57·2	10	E.N.E.; E.S.E.
	1877.							
7	Jan. 1– 2	1243	28·66	51·8	28·70	59·7	10	S.W.; E.
8	Jan. 9–10	1019	29·29	60·2	29·13	63·5	9	S.W.
9	Jan. 19–20	1190	29·06	53·0	29·13	66·0	8	S.W.; S.S.W.; S.; S.S.E.; S.E.
10	Feb. 10–11	1155	----	55·5	29·13	55·0	9	W.; W.S.W.; S.W.
11	Oct. 14–15	1007	28·82	66·0	29·13	66·0	10	W.N.W.; S.S.W.; S.

It will be seen that the number of European cases in which storms advance 1000 miles in a day, amounts to 11 in two years, being an average of 5½ cases annually; the greatest rate of progress observed is 1330 miles in a day; these storms generally advanced toward a point north of east, and in no case was there a considerable movement toward the south of east; the average height of the barometer at the center was 29·0 inches; and they were all accompanied by winds of great violence.

In the United States, the cases in which storms advance with a high velocity are of much more frequent occurrence, and they sometimes attain a velocity greater than has been observed in Europe, but the amount of the barometric depression is much less. In my first paper (this Journ., vol. viii, p. 4) I alluded to these examples of high velocity, and showed that in these cases the rain-area extended eastward of the storm's center to an unusual distance. The same subject was further considered in my third paper (this Journ., vol. x, p. 6).

I now present a summary of the cases in which barometric minima advanced at least 1000 miles in a day, during the period for which the observations of the Signal Service have been published entire, viz: Sept., 1872, to Jan., 1875, and January to March, 1877. In the following table, column 1st gives the number of reference; column 2d gives the date of commencement of the day in question, where 1 denotes the 7·35 A. M. observation, 2 the 4·35 P. M. observation, and 3 the 11 P. M. observation; column 3d shows the distance in English miles that the storm advanced in twenty-four hours; column 4th (increased by twenty-eight inches) shows the height of the barometer at the center of the low area at the beginning of

the given day; column 5th shows the station at which the height mentioned in the preceding column was observed; column 6th (increased by 28 inches) shows the height of the barometer at the center of the low area at the end of the given day; column 7th shows the station at which the height mentioned in the preceding column was observed; column 8th shows the direction and velocity (in miles per hour) of the highest wind at any of the stations near the low center during the given day; column 9th shows the direction and velocity of the highest wind on Mt. Washington observed during the progress of the storm or immediately after the storm had passed eastward; column 10th shows the total rainfall at the Signal Service stations within the low area (barometer below thirty inches) during the day in question; column 11th shows the distance that the rain area extended eastward of the center of least pressure; column 12th shows the distance eastward from the storm-center that abnormal winds extended (that is, winds from S., S.E., E. or N.E.); column 13th shows the direction of an area of high barometer, with reference to the low center; and column 14th (increased by thirty inches) shows the greatest height of the barometer within the high area mentioned in the preceding column.

Besides the cases here enumerated there are a few others in which storms may have advanced with equal rapidity, but there is so much uncertainty with regard to the exact position of the center of least pressure that I have preferred to leave them out of the account. The number of cases in the table is 39, occurring within a period of 32 months which gives an average of 14 per year, being 2½ times as many as occur in Europe. The greatest observed velocity of these low areas was 1872 miles per day, which is 40 per cent greater than the highest velocity observed in Europe.

The average height of the barometer at the beginning of the days enumerated was 29·62 inches, and the average height at the end of the days was 29·42 inches, which is only half of the average depression observed in the storms of Europe. In 27 of these cases the depression at the center of the storm increased during the day, in 11 cases it decreased, and in one case it remained stationary. In each of these last 12 cases except Nos. 31, 37 and 38, the center of low barometer passed north of the United States, and it is doubtful whether the lowest barometer was observed. Thus we see that in the American cases, the storms generally increased in intensity, while in the European cases there was a slight diminution of intensity.

The highest wind recorded at any station during the days in question (excluding Mt. Washington and Pike's Peak) ranged

Barometric minima advancing at least 1000 miles in 24 hours.

No.	Date.	Progress, miles.	Barometer, inches.	Station.	Barometer, inches.	Station.	Highest wind.	Wind on Mt. Wash.	Rain. In Low, inches.	Rain. Extent, miles.	Abnor. winds, miles.	High Bar Direction.	High Bar Amount, inches.
	1872.												
1	Nov. 6.2	1376	1·45	Pembina	1·12	Portland	N. 41	N.W. 65	15·08	1357	1357	S.E.	·19
2	24.2	1214	1·62	Keokuk	1·39	Quebec	W. 36	W. 85	0·44	429	1056	S.E.	·30
3	Dec. 14.1	1132	1·67	Omaha	1·51	Montreal	N.W. 32	N. 68	0·18	134	541	S.E.	·45
4	19.1	1295	1·70	Indianola	1·43	Buffalo	N.E. 33	N.E. 55	11·59	650	1220	N.E.	·52
	1873.												
5	Jan. 4.3	1215	1·74	Memphis	1·33	Portland	N.E. 42	S. 64	30·66	462	983	N.E.	·35
6	26.3	1404	1·80	Lake C'y	1·17	Halifax	N. 40	W. 54	9·71	944	1118	N.E.	·21
7	Feb. 15.3	1055	1·59	Memphis	1·53	N. London	N.E. 36	N.E. 60	20·19	948	1042	N.E.	·48
8	May 12.2	1145	1·44	St. Paul	1·35	Portland	N. 30	N.W. 72	3·22	318	543	S.	·08
9	Nov. 3.3	1100	1·49	Duluth	1·60	F. Point	N. 30	N.W. 65	0·00	000	727	S.E.	·36
10	23.1	1270	1·73	Indianola	1·48	Pittsburgh	N.E. 47	N.W. 72	11·57	1058	1270	N.E.	·48
11	24.1	1002	1·48	Pittsbu'gh	0·82	Halifax	N.E. 59	N.W. 72	28·39	640	917	N.E.	·34
	1874.												
12	Jan. 3.3	1000	1·31	Escanaba	1·55	F. Point	N. 40	S.W. 80	4·92	00	1270	S.E.	·33
13	Feb. 6.2	1212	1·82	Louisv'e	1·70	Sydney	S.W. 36	N.W. 108	11·94	780	728	N.E.	·36
14	19.1	1123	1·52	Duluth	1·70	F. Point	S.W. 67	S. 72	1·54	846	1030	S.E.	·44
15	22.1	1374	1·89	Indianola	1·58	Rochester	E. 65	W. 92	3·44	1226	1700	E.	·27
16	23.1	1058	1·58	Roches'r	1·47	F. Point	E. 65	W. 92	9·76	783	947	S.E.	23
17	March 3.1	1114	1·29	Leaven'th	1·34	Ottawa	S. 35	S.W. 96	12·30	676	1424	S.E.	·13
18	18.2	1187	1·63	Keokuk	1·19	Quebec	W. 35	N.W. 110	15·83	1011	1607	E.	·24
19	April 5.1	1065	1·71	St. Louis	1·63	Ottawa	S.W. 40	N.W. 60	8·45	488	663	E.	·51
20	Sept. 2.1	1175	1·89	St. Paul	1·72	F. Point	N.W. 18	N.W. 82	0·96	360	464	S.E.	·22
21	Nov. 28.1	1466	2·15	Mobile	1·54	Quebec	N.E 50	N.W. 100	1·04	1025	1080	N.E.	·48
22	Dec. 2.2	1095	1·44	Marqu'e	1·64	C. Rozier	N.W. 41	N.W. 76	0·33	596	744	S.E.	·38
23	13.2	1092	1·83	Cleve'nd	1·42	Halifax	N. 52	N.W. 98	6·17	668	835	S.E.	·25
24	16.1	1065	1·51	Omaha	1·59	Ottawa	N.W. 40	N.W. 85	5·65	572	1170	S.E.	·56
25	23.2	1165	1·49	Marqu'e	1·37	Halifax	W. 39	N.W. 80	1·63	426	640	S.E.	·16
26	27.2	1134	1·59	Bismark	1·59	Quebec	S.W. 30	N.W. 100	8·91	663	956	S.E.	·21
	1875.												
27	Jan. 1.3	1170	1·94	Marqu'e	0·89	Halifax	W. 44	N.W. 90	15·59	668	671	S.E.	·43
	1877.												
28	Jan. 1.1	1126	1·62	St. Marks	1·35	Boston	E. 50	N.W. 100	21·25	643	936	N.E.	·21
29	6.1	1048	1·84	Mobile	1·15	New York	N.W. 68	N.W. 96	12·72	577	1223	N.E.	·33
30	7.3	1872	1 84	Indianola	1·37	Eastport	N. 52	N.W. 96	4·08	1080	922	S.E.	·09
31	15.1	1270	1·45	F. Gibson	1·56	Malone	N. 48	N.W. 84	20·68	1158	1275	N.E.	35
32	19.1	1080	1·63	Bismark	1·19	Parry S.	N.W. 36	N.W. 96	1·55	321	840	S.E.	·35
33	March 1.2	1003	1·56	Memphis	1·07	Parry S.	S. 42	N.W. 84	23·21	905	991	E.	·23
34	3.2	1178	1·61	Indian'lis	1·52	F. Point	S. 31	N.W. 102	9·89	758	958	S.	·19
35	6.2	1055	1·59	Escanaba	1·71	Chatham	W. 32	N.W. 72	3·25	270	705	S.	·33
36	8.2	1061	1·16	Cincin'i	0·74	F. Point	S. 50	N.W. 72	36·24	1080	1080	N.E.	·43
37	15.3	1050	1·56	Dodge C.	1·64	Knoxville	N.W. 44	N.W. 60	3·57	839	839	S.E.	·18
38	18.3	1209	1·66	Leaven'th	1·87	C. Henry	N.W. 40	N.W. 60	1·11	457	1206	S.E.	·32
39	20.2	1047	1·55	St. Louis	1·57	Malone	N. 36	N.W. 60	11·89	593	1037	E.	·30
	Means		1·62		1·42		42·1	80·4	9·97	667	993		

from 18 to 68 miles per hour. In the case of No. 20, winds higher than 18 miles per hour prevailed in other parts of the United States, but it is doubtful whether they ought to be regarded as belonging to the storm here investigated. The average of the numbers in this column of the table is 42 miles per hour. The number of cases for the different points of the compass is shown in column 2d of the following table.

	Cases.	Mt. W.		Cases.	Mt. W.
North	9	1	South	4	2
North West	8	28	South East	0	0
West	5	4	East	3	0
South West	4	2	North East	6	2

Thus we see that in 28 of the cases, the highest wind came from the quarters N.E., N., N.W. and W.; and in only 11 of the cases did they come from the quarters S.W., S., S.E. and E. The average direction of these violent winds was about N.N.W. while in Europe it was but a little west of south.

On Mt. Washington the highest winds range from 54 to 110 miles per hour, the average being 80 miles. The number of cases for the different points of the compass is shown in column 3d of the preceding table, and we see that in 35 of the cases the highest wind came from the points N.E., N.W. and W.; while in only 4 of the cases did they come from the points S.W., S., S.E. and E.

The average rainfall in 24 hours within these low areas was 0·97 inches, which is considerably in excess of the usual rainfall at the same stations. The amount of the rain was however very variable, ranging from 0 to 36 inches; and there were ten cases in which the total rain-fall within the low area was less than two inches in 24 hours. In 6 of these 10 cases the storm center passed beyond the northern boundary of the United States or very near to it, and it may be claimed that probably there was rain on the north side of these low areas; but in Nos. 2, 3 and 38, the center of the low area was 500 miles south of our northern boundary. No. 21 was a peculiar case. On the morning of Nov. 28, 1874, the lowest barometer at any of the signal service stations was 30·15 inches, so that the barometer at Mobile was only *relatively low*, the pressure being unusually high from the Atlantic to the Pacific Ocean. In preparing column 8th of the table, it was necessary to have a uniform rule which could be applied without bias, and I have regarded the term low as including all stations surrounding the storm center, where the barometer was below 30 inches. This rule indicated no rain for the morning and afternoon observations of Nov. 28th, although in fact there was a great fall of rain and snow within the system of winds which

circulated about Mobile. If all this precipitation is regarded as belonging to the storm No. 21, it makes a total of 17·60 inches for that day. No. 15 presents another case in which the rain-fall in column 8th is made to appear very small in consequence of the rule above stated, but if all the rain included within the system of circulating winds for that day were counted, the total would be 12·19 inches. We see then that these cases of fast moving barometric minima were generally accompanied by a large rain-fall; but there are apparently some cases in which the rain-fall which can be associated with these low areas was very slight. Such were Nos. 2, 3 and 38.

The area of rain generally extended a great distance in advance of the storm center, the average distance being 667 miles, but there were several cases in which the rain extended but little eastward of the storm center. These were generally cases in which the rain-fall shown in column 10th was very small, but No. 12 was a case in which the rain-fall was considerable, yet for each period of eight hours the rain did not extend sensibly eastward of the center of least pressure at the close of the eight hours. This implies that the rain did actually extend eastward of the low center to a distance equal to the space traveled over by the storm center in about four hours, that is, 200 miles; but on the morning of January 4th the center of the rain area very nearly coincided with the center of least pressure, and was apparently a little westward of that center.

The abnormal winds generally extended on the east side of the low center to a distance of about 1,000 miles, the average being 993 miles. By abnormal winds I understand winds from the south, southeast, east or northeast. No. 20 is the only instance in which this distance was less than 500 miles; and in this case there was another low center at a distance of 1,500 miles on the east side, the two being separated by a narrow ridge of higher pressure, in which the highest barometer was 30·15 inches. This ridge of higher pressure separated two systems of circulating winds, and was apparently levelled before the morning of September 3d.

What now is the cause of these rapid movements of storm centers? Several of them apparently resulted from the mutual influence of two low areas. In my 10th paper (this Journ., vol. xvii, p. 5) I showed that on the Atlantic Ocean two low areas frequently become merged in one. In such cases the eastern low area is generally retarded in its progress, and is sometimes turned backward toward the west. At the same time the progress of the western low area must be accelerated. Such cases appear to occur within the limits of the United States, or near our borders, although the geographical extent of the weather maps is too small to exhibit the full development of

these changes. Nos. 3, 6, 8, 9, 13, 15, 18, 19, 20, 25, 27, 28, 29, 30, 33, 34, 35, 37 and 38 were apparently of this kind.

The maps accompanying the Hamburgh Review for January, 1877, clearly show that No. 7 of the cases on page 101 belongs to this class. I have no information which enables me to judge of the other European cases on page 101.

The cases of barometric minima enumerated in the table on page 103 were all accompanied with high winds and some of them with violent winds; they were generally accompanied with a great fall of rain or snow, and the rain-area generally extended to a great distance in front of the storm's center; but the most noticeable circumstance which characterizes all the cases is the great extent of abnormal winds in front of the storm's center. These abnormal winds were apparently due to an area of high barometer situated on the south, southeast, east or northeast side of the low center. These winds (in consequence of the rotation of the earth) tend to produce a depression of the barometer on their left side. They were generally accompanied with a considerable rain-fall, which tends to increase the velocity of the winds and thus produce a greater depression of the barometer.

In order to illustrate more clearly the operation of these different causes, I have prepared Plate IV, which shows the isobars and winds for January 15, 1877, at 4.35 P. M. (case No. 31 of the table on page 103). We see that the center of the low area was between Cincinnati and St. Louis, the lowest pressure recorded being 29·39 at Cincinnati. Around this center the isobars are arranged with considerable symmetry, but are crowded most closely together on the northwest side, and we find an area of high pressure (30·46) whose center is not far from Breckenridge. Also on the northeast side near the margin of the chart, we find another area of high barometer (30·35). The winds tend from these high centers toward the low center, but by the rotation of the earth they are deflected to the right, thus producing an increased pressure on the right of their course, and a diminished pressure on their left. The movement due to these causes would soon cease if there were no recruiting force. This force is supplied by the precipitation of the vapor which is present in the air. When this vapor is condensed, the neighboring air rushes in with great force to supply the place of the condensed vapor, and the air is expanded by the latent heat which is set free. This cause is sufficient to maintain high winds as long as there is a great precipitation of vapor.

On Plate IV the direction of the wind is indicated by arrows; and the force of the wind is indicated by the number of feathers attached to the end of the arrows. One feather indicates a

velocity not exceeding five miles per hour; two feathers indicate a velocity from six to ten miles; three feathers from eleven to fifteen miles; four feathers from sixteen to twenty miles, and so on for higher velocities.

The center of low pressure advanced eastward along the dotted line represented on Plate IV. Some have claimed that this advance of storms is simple *drift*, the entire mass of air within the low area being carried bodily eastward, that being the average direction in which the atmosphere moves in the middle latitudes. This explanation will not stand examination. If while the winds are circulating around a low center, the entire atmosphere within the low area is carried bodily eastward, the effect of this movement should be different upon the northern and southern portions of the storm. In my former papers I have shown that on the north side of low areas in the United States the average direction of the wind is nearly northeast, and on the south side it is from the southwest, and the average velocity of the winds on both sides is nearly the same, viz: eight miles per hour, while the average progress of the low center is twenty-six miles per hour. Suppose now the velocity of progress to be increased to fifty miles per hour, if the entire mass of air within the low area is carried bodily eastward, the velocity of the wind relative to the earth's surface should be greatly increased on the south side of the low area, while that on the north side should be diminished, and the direction of the wind on each side should be materially changed. But we see from Plate IV that on the north side of the low center the winds blow from the northeast with an unusual velocity, while those on the south side generally blow from the southwest and are comparatively feeble. If we compare the stations within the isobar 29·9 we find that on the north side of the track of the storm, the average velocity of the winds is 14·9 miles per hour, and on the south side it is 8·5 miles; that is, on the north side the average velocity of the winds is seventy-five per cent greater than it is on the south side. The air within this low area did not then drift bodily eastward, but the eastward movement of the storm was due to some other cause.

The same conclusion applies to areas of high barometer, as will appear from a comparison of a few well-established facts. In a former paper I have shown that in the United States the average rate of motion of areas of high barometer is about twenty-five miles per hour. I have also shown that the winds blow outward from areas of high barometer, and therefore at the center there must be a *calm*, as observation generally indicates. If the area of high barometer was a mass of air advancing bodily from place to place at the rate of twenty-five miles per hour, the wind at the center should blow at the rate of

twenty-five miles per hour. We must then conclude that the progressive movement of areas of high barometer is like that of a wave, and its apparent motion results from a subtraction of air from one side and an addition of air to the opposite side.

The progress of areas of low barometer must be due to similar causes. The pressure is diminished on the east side of the low area and increased on the west side, in consequence of which the low center suffers a displacement with reference to the earth's surface, and the rate of progress of the low center will depend upon the rate at which the pressure is reduced on the east side, and restored on the west side.

The advance of storm centers across the United States may be affected by atmospheric conditions prevailing much beyond the limits of the signal service maps, so that we cannot be sure that we know all the circumstances which influence the case we are considering, but from Plate IV we can see a reason why the pressure on the west side of the low area should be rapidly restored. The air from the north and northwest rushed in with great velocity. This air had a very low temperature, the thermometer at 4.35 P. M. (Washington time) being below zero of Fahrenheit at Pembina, Bismark, Breckenridge, Fort Sully, Yankton, North Platte and Omaha. On the northeast side of the low center the wind was generally from the northeast, by which means the air was drawn off from that region and the pressure diminished. But if no other force operated, the low area would soon be filled up by these movements of the atmosphere, and the pressure would resume its normal state. This result is prevented by the condensation of the vapor which is present in the air. The rain which fell during the nine hours from 7.35 A. M. to 4.35 P. M. is exhibited on Plate IV by dotted lines. We see that a slight fall of rain or snow covered nearly the entire United States east of the meridian of 100°, but the greatest fall was at Louisville (1·56 inches in nine hours); and the area of one-quarter inch rain-fall extended from Lacrosse on the north, to Vicksburg on the south, and Boston on the east. The moist and warmer air on the east side of the low center rises from the earth's surface and is supplanted by the cold air which presses in upon the west side. The great extension of the rain area on the east side causes an unusually rapid fall of the barometer on that side, and a corresponding advance of the storm's center.

We have seen from the table on page 99 that in the middle latitudes, storms generally travel eastward, even though the principal rain-fall should be on the west side of the low center; but when the principal rain-fall is on the east side of the low center, this causes a diversion of the winds in that direction, and the low center travels eastward with increased rapidity.

During the entire progress of the storm of January 14–17, 1877, the winds on Mt. Washington blew uninterruptedly from the northwest, and the least velocity reported was thirty-six miles per hour, showing that the movements represented on Plate IV were confined to the lower stratum of the atmosphere and did not reach to the height of 6,000 feet.

Most of the cases enumerated in the table on page 103 agree with No. 31 in several of the particulars here stated. Their rapid movement eastward appears to have been due to an unusual extension of easterly winds which seem to have owed their origin to the accidental proximity of areas of high barometer, and the influence of this high barometer was sustained by the precipitation of vapor which extended to an unusual distance on the east side of the low center.

In the table on page 103 are a few cases to which the explanation here given does not seem to apply. The rapid movement of Nos. 2 and 3 was apparently due to their position between two areas of high barometer, one on the northwest side and the other on the southeast. In order to maintain these areas of high barometer, it seems necessary to admit the existence of rain in some region not shown by the Signal Service observations. These examples illustrate the importance of having observations from a large portion of the earth's surface, in order that we may fully investigate the phenomena of particular storms.

In preparing the materials for this article I have been assisted by Mr. Henry A. Hazen, a graduate of Dartmouth college, of the class of 1871.

ART. XIII.—*On the Color Correction of Achromatic Telescopes; A reply to* Prof. CHAS. S. HASTINGS; by WM. HARKNESS.

IN the December number of this Journal, pages 434, 435, the distinguished Associate Professor of Physics of the Johns Hopkins University has criticised my theory of the color correction of achromatic telescopes in language which I quote here to avoid the possibility of misrepresenting it; merely adding numbers to the clauses for convenience of reference:

"These results are directly opposed to those of a recent writer in this Journal (Prof. Harkness in the Sept. number, pp. 191–193). But his conclusions arise from erroneous calculations. (I) Not only does his interpretation of his equation (12) imply the manifest absurdity that in a system of infinitely thin lenses in contact its properties are determined by the order of the lenses, but the interpretation is impossible. True A_2 should have an opposite sign to $A_1 + A_3$, but that asserts nothing as to likeness of the latter symbols in sign. (II) Thus n in equation (16) may be negative

and consequently his subsequent reasoning is fallacious, for in that case n does not have to be infinite to cause equation (27) to vanish. (III) I may add that the origin of the confusion is in making the ratio $D \div E$ in equation (9) constant; it may be, and of course should be, indeterminate."

"(IV) Professor Harkness has made another mistake, founded upon inadequate experiment, which has so important a bearing on the theory of the double objective that it should not be allowed to pass uncorrected. His statement (p. 191) concerning the condition for color correction is substantially correct, though in my opinion, it is not self-evident but requires proof. This proof I shall supply in a forthcoming number of the American Journal of Mathematics. (V) His experiment, however (p. 193), directly contravenes this principle, for he finds that the focal plane does not correspond to the minimum focal distance, but to something greater. (VI) The source of error is the introduction of a variable element in the system, namely, the eye, which would adjust itself differently in observing the star and its spectrum. Had the writer used eye-pieces of successively higher power, thus lessening progressively the power of accommodation of the system, with his prism, he would have seen his points γ_m and γ_n approach until they sensibly coincided; or better still had he formed his spectrum by a grating (such as perforated cardboard) before the objective, instead of by a prism between the ocular and eye, he could not have been misled, since the uncolored image would serve to control the eye."

"(VII) Finally, the fourth conclusion (p. 196) is strictly true, though we are not to conclude, as would seem from the text, that the detriment due to the secondary spectrum depends either solely upon the aperture or varies inversely as the focal length; * * *"

Let us examine this criticism in detail; referring to its clauses, and to the equations of my original paper, by their respective numbers.

Clause I virtually asserts that three quantities can be arranged in two classes otherwise than by putting one in one class and two in the other. To prove this we remark that equation (12) may be written

$$0 = A_1(b_1 + 2c_1\gamma_0^2) + A_2(b_2 + 2c_2\gamma_0^2) + A_3(b_3 + 2c_3\gamma_0^2) \quad (36)$$

For all glasses of which I have any knowledge, b is positive, and very much larger than c. The latter quantity is sometimes negative; but when this happens, it is exceedingly small. γ cannot be otherwise than positive. From these conditions it results that the quantities $(b + 2c\gamma_0^2)$ are invariably positive, and therefore the sign of each term in (36) depends solely upon the sign of its A. But in order that (36) may be true, one of its terms must have a different sign from the other two; and just because the properties of a system of infinitely thin lenses

in contact are independent of the order of the lenses; the choice of this term is arbitrary. Taking advantage of this circumstance to follow the usual practice of opticians, I made the middle lens different from the other two, and wrote

$$-A_2(b_2+2c_2\gamma_0^2)=A_1(b_1+2c_1\gamma_0^2)+A_3(b_3+2c_3\gamma_0^2) \quad (37)$$

But Clause I declares, "True A_2 should have an opposite sign to $A_1 + A_3$, but that asserts nothing as to likeness of the latter symbols in sign."—A statement which is manifestly untrue, unless it can be shown that three quantities can be arranged in two classes otherwise than by putting one in one class and two in the other.

Clause II asserts that n, in equation (16), may be negative. This is absurd, because $n = A_3 \div A_1$, and it has just been shown that the signs of A_1 and A_3 are always similar.

Clause III declares that $D \div E$ should be indeterminate; and that all my alleged errors arise from making it constant. Referring to equations (6), we see that

$$\begin{aligned} D &= A_1b_1 + A_2b_2 + A_3b_3 \\ E &= A_1c_1 + A_2c_2 + A_3c_3 \end{aligned} \quad (6)$$

The A's depend only upon the curves of the lenses, while the b's and c's depend only upon the physical properties of the glasses employed. In designing an objective D and E are both so far arbitrary that any glasses, and any curves, may be chosen; but when the objective is completed I certainly do hold that its curves, and the physical properties of the pieces of glass composing it, are constant. If I am right in this, it follows that both D and E, and also their ratio are constant; Clause III to the contrary notwithstanding.

Clause IV admits the accuracy of my statement that an objective is properly corrected for any given purpose when its minimum focal distance corresponds to rays of the wave-length which is most efficient for that purpose; but says the statement requires proof, and is not self-evident. With the law of dispersion assumed in equation (2), the focal curve can have but one tangent parallel to the axis of abscissas; and I did not suppose it necessary to tell the readers of this Journal that the parts of such a curve nearest the tangent line are those adjacent to the point of tangency. That consideration proves my proposition, and it is so elementary that I thought it self-evident. If more than two lenses, and a dispersion formula involving more than two powers of the wave-length, are assumed; I venture to say that the condition for color correction stated above cannot be proved. It may be true in special cases; but in general, the focal curve will have such a form as to give more than one minimum focal distance.

Clause V involves the assumption that the focal plane must be tangent to the focal curve at the point where the latter makes it nearest approach to the objective. No reason is assigned for this, and I do not believe any exists.

Clause VI virtually asserts that the focal distance of an objective is a function of the power of its ocular. For all astronomical instruments carrying filar micrometers, the first business of the observer is to place the wires accurately in the focus of the objective. This once done, they are not again disturbed, unless to make some radical change in the instrument. A dozen eye-pieces may be used in the course of a single evening; but no matter what their power, when they are focused upon the wires they are always found to be focused upon the objective. Hence, the focal plane always coincides with the wires. But the plane of the wires is fixed; and the focal curve, as I have defined it, is also fixed. Consequently, the points of intersection of the focal plane with the focal curve are fixed, and the universal experience of astronomers demonstrates that the positions of the points γ_m and γ_n do not vary with the power of the ocular.

As *Clause VII* affirms the correctness of my fourth conclusion, it is only necessary to express my thanks for such an indorsement; but I cannot refrain from adding that, since this clause rests upon equations condemned by my critic, there may be people wicked enough to inquire how these erroneous equations finally led to a correct result.

In this connection it is desirable to state that some months ago I investigated the relations existing in achromatic objectives between aperture, focal length and secondary spectrum. As the admissible limit of the latter of these elements is arbitrary, it is not possible to fix absolutely the relations between the other two; but I believe the focal distance should rarely be less than that given by the formula

$$F = (9{\cdot}04\alpha^2 + 1296)^{\frac{1}{2}} - 36 \qquad (38)$$

in which F is the focal distance, in feet; and α the clear aperture in inches. For small apertures, the foci given by this expression are inconveniently short; while for large apertures, they considerably exceed those in general use.

Now consider a system of infinitely thin lenses in contact; and let us inquire how many lenses are needed in the system, to bring the greatest possible number of light-rays of different degrees of refrangibility to a common focus, with any given law of dispersion.

For this purpose we revert to equation (5), which may be written

$$f^{-1} = (\mu_1 - 1)A_1 + (\mu_2 - 1)A_2 + (\mu_3 - 1)A_3 + \&c. \qquad (39)$$

the number of terms being unlimited. For the dispersion formula, we write

$$\mu = \varphi(\lambda) \tag{40}$$

The form of $\varphi(\lambda)$ is regarded as unknown; but there will be no loss of generality if it is developed in a series arranged according to the powers of λ. We therefore have

$$\mu = a + b\lambda^m + c\lambda^n + e\lambda^p + \&c. \tag{41}$$

in which a, b, c, etc., are constants, and the number of terms may be taken as great as is desired. Also, let us put

$$\begin{aligned} C &= A_1(a_1 - 1) + A_2(a_2 - 1) + A_3(a_3 - 1) + \&c. \\ D &= A_1 b_1 - A_2 b_2 + A_3 b_3 + \&c. \\ E &= A_1 c_1 + A_2 c_2 + A_3 c_3 + \&c. \\ F &= A_1 e_1 + A_2 e_2 + A_3 e_3 + \&c. \\ &\&c. \quad \&c. \quad \&c. \quad \&c. \end{aligned} \tag{42}$$

the number of these equations, and the number of terms in the right hand member of each of them, being the same as the number of terms in the right hand member of (41). Then, by a simple transformation (39) becomes

$$f^{-1} = C + D\lambda^m + E\lambda^n + F\lambda^p + \&c. \tag{43}$$

This is the equation of the focal curve; λ being the abscissa, and f the ordinate. Its first derivative is

$$\frac{df}{d\lambda} = -f^2(mD\lambda^{m-1} + nE\lambda^{n-1} + pF\lambda^{p-1} + \&c.) \tag{44}$$

which, as is well known, expresses for every point of the curve the tangent of the angle made by the tangent line with the axis of abscissas. The number of rays of different degrees of refrangibility, which can be brought to a common focus, will evidently be the same as the number of times the focal plane intersects the focal curve. But the focal plane is necessarily parallel to the axis of abscissas; and therefore the greatest possible number of intersections of the curve with the plane can only exceed by one, the number of tangents which can be drawn parallel to the axis of abscissas. To find these tangents, we equate (44) to zero, and obtain

$$0 = mD + nE\lambda^{n-m} + pF\lambda^{p-m} + \&c. \tag{45}$$

As λ can never be either zero, imaginary, or negative, we have to consider only the real positive roots of this equation; each of which corresponds to a tangent. To make the number of roots as great as possible, the quantities D, E, F, etc., must be independent of each other; which will be the case when the right hand members of the equations (42) contain as many A's as there are powers of λ in (41). Hence it is evident that the number of real positive roots in (45) will be one less than the number of powers of λ in (41), and we conclude that—

In any system of infinitely thin lenses in contact, the number of lenses required to bring the greatest possible number of light-rays of different degrees of refrangibility to a common focus is the same as the number of different powers of λ involved in the dispersion formula employed.

The method used in deducing this result was adopted because it exhibits clearly the geometrical relations of the problem. The result itself is evident from a mere inspection of equation (43), which cannot possess more real positive roots than it has independent coefficients, D, E, F, etc.

The color correction of an objective depends only upon the form of its focal curve; which form is as much under control as the nature of the case admits when the coefficients D, E, F, etc., of equation (43), are independent of each other. This, taken in connection with what precedes, demonstrates that—

In an objective consisting of a system of infinitely thin lenses in contact, the color correction cannot be improved by increasing the number of lenses beyond the number of different powers of λ involved in the dispersion formula employed.

This result confirms the conclusion of my former paper, in which I used a dispersion formula involving but two powers of the wave-length, and consequently found but two lenses necessary in an achromatic objective. It also throws a curious light upon the general theory of achromaticity. If the law of dispersion had been such as could be expressed by a function involving but a single power of the wave-length, there would have been no irrationality of spectra, the mean dispersive powers might have been just what they now are, and yet, Newton would have been right in saying that achromatic telescopes were an impossibility. Conversely, the greater the number of powers of the wave-length involved in the dispersion function, the greater the number of rays of different degrees of refrangibility which can be brought to a common focus; and this, irrespective of any irrationality which may exist in the spectra. With rational spectra, and a law of dispersion involving at least two different powers of the wave-lengths, a pair of lenses would suffice for the construction of a perfectly achromatic objective. In strictness, these statements apply only to objectives consisting of infinitely thin lenses in contact. Possibly they may require modification when the thicknesses and distances apart of the lenses are considered.

The text books teach that the condition of achromatism for two thin lenses in contact is

$$0 = p_2 f_1 + p_1 f_2 \qquad (46)$$

in which f_1 and f_2 are the foci, and p_1 and p_2 the dispersive powers, of the lenses. They further teach that it is sufficiently accurate to put

$$p = \frac{\delta\mu}{\mu - 1} \tag{47}$$

in which $\delta\mu$ is the difference, and μ the mean, of the refractive indices for the rays D and F. For a law of dispersion involving at least two different powers of the wave-length, these equations will hold; but for a law involving only a single power of the wave-length, they may be satisfied, and yet the system of lenses will not be achromatic. Instead of embodying, these equations are actually independent of, the essential condition of achromatism; which is that at least two rays of widely different wave-length must be brought to a common focus.

I have not had leisure to examine my critic's figures; nor does it seem worth while to do so. My equation (2) represents refractive indices with an accuracy of about four and a half places of decimals, while most of the authorities upon whom he relies only give these quantities to five places of decimals. If this difference of five units in the fifth place of decimals can originate such changes in the focal curve as he supposes, it is evident that trustworthy conclusions can only be reached by using very accurate dispersion formulæ. Cauchy's formula, as written in equation (2), has hitherto been most used; but when compared with the best observations, the residuals, although small, show some constancy of sign. It has recently been claimed* that Briot's formula, which is

$$\mu = a + b\lambda^{-2} + c\lambda^{-4} + k\lambda^{2} \tag{48}$$

represents the best observations, throughout the whole space from the extreme ultra-red to the extreme ultra-violet, within the limits of accidental error. If such is the case, a triple objective may possibly be better than a double one; but my critic's figures certainly do not suffice to prove this. They are founded upon a formula whose independent variable is not the wave-length of the light, but the refractive index of a standard piece of glass; and his Table II, page 432, shows that when compared with observation this formula yields residuals exhibiting as much constancy of sign, and almost the same magnitude, as those given by my equation (2). The use of any independent variable other than the wave-length, is likely to produce erroneous results, and certainly does not tend to elucidate the subject.

Having seen that a dispersion formula involving only three powers of the wave-length suffices to represent the best observations, and remembering that this circumstance limits the number of lenses which can be employed with advantage in an

* By M. Mouton, in the Comptes Rendus, 1879, vol. lxxxviii, p. 1190.

objective to not more than three; we are now in a position to appreciate the absurdity of my critic's assertion, page 429, when, enquiring if it is possible to eradicate the secondary spectrum by increasing the number of lenses in an objective, he says, "Theoretically, since a new disposable constant for color change is introduced with each lens in the system, the answer is evidently affirmative; * * *"

For an objective consisting of more than two lenses, and a law of dispersion involving more than two powers of the wave-length, the condition given in my former paper, page 196, for the best color correction, is no longer applicable. The problem then becomes very complex, but I am inclined to think that it is satisfactorily solved by attributing to each element of the focal curve a mass proportional to its efficiency for the purpose for which the correction is required, and varying the curve until its moment of inertia about its intersection with the focal plane becomes a minimum. It is also probable that this condition will suffice to determine the relative merits of double and triple objectives; the focal curve with the smallest moment being the best.

Finally, it only remains to reiterate that the conclusions of my former paper are certainly correct to the degree of accuracy involved in my fundamental equations—that is, for a system of infinitely thin lenses in contact, and for the law of dispersion embodied in equation (2). For a different law of dispersion, or if the thicknesses and distances apart of the lenses are considered, these conclusions may require modification.

Washington, Dec. 29, 1879.

ART. XIV.—*Pinite in Eastern Massachusetts: its Origin and Geological Relations;* by W. O. CROSBY.

ONE of the most interesting constituents of the conglomerate so extensively developed in the vicinity of Boston is a soft, greenish and somewhat unctuous, amorphous mineral, which many observers have mistaken for serpentine, but which is shown by its ready fusibility not to be magnesian; while analysis proves that it is essentially a hydrous alkaline silicate of aluminum. In fact, it presents in its chemical, as well as its physical, characters a close agreement with the species pinite. (See analyses below). The hardness is ordinarily near, or a little above, 3; the purer varieties, however, usually refuse to scratch calcite. The specific gravity, so far as determined, is between 2·7 and 2·75. Luster none, or waxy and feebly shining. The predominant color is a whitish-green; but the variation is from nearly white through whitish, grayish and dirty

greens to a dull grass or olive green. The deeper color seems usually to belong to the purer varieties.

At some points, the paste or cement of the conglomerate appears to include much pinite; yet in its purest state this substance occurs mainly in the form of pebbles. In either case, however, it is always clearly an imported constituent of the rock. Although not properly a principal ingredient of the conglomerate, the pinite detritus is scarcely ever entirely wanting; while in several limited localities the rock is mainly composed of it; forming a distinct pinite conglomerate. The following are the principal localities in the Boston basin where the conglomerate is notably rich in pinite: the north shore of Squantum; Milton, on and near Central Avenue; several points in Newton, especially in the vicinity of Newton Corner and Newton Upper Falls; and along the line of the Sudbury River Aqueduct in South Natick.

The pinite pebbles, probably on account of their inferior hardness, being permanently plastic, as it were, are usually very much flattened in parallel planes; giving rise, where they are sufficiently abundant, to a decidedly schistose structure in the rock, or more properly an imperfect cleavage. This cleavage structure in the pinite conglomerate is very clearly the result of pressure, and shows a nearly constant dip and strike in all parts of the district; being entirely independent of the stratification, and agreeing perfectly in all these respects with the cleavage of the slate rocks. Where the pinite pebbles are scattering, they are sometimes found as contorted layers enveloping pebbles of harder materials.

The distinctly stratified rocks of the Boston basin include two principal varieties—the conglomerate, or "Roxbury pudding stone," and the slate. The volume of each of these varies from four hundred or five hundred to perhaps one thousand feet; and the former constitutes the lower half and the latter the upper half of one continuous and conformable series. The upper or argillaceous member of the formation includes the Paradoxides slate in Braintree; and this determines the Primordial age of the entire series. The slate, and more especially the sandstone which marks the passage from the slate to the conglomerate, is sometimes greenish and evidently composed in part of the débris of pinite. The sediments in the basin of the River Parker, some thirty miles northeast of Boston, are also probably of Primordial age; and the conglomerate portions are largely, sometimes almost entirely, composed of pinite. Traces of this mineral have been frequently observed in the conglomerate of uncertain age skirting the southern base of the Blue Hills, and extending thence southwesterly to Rhode Island.

The pinite is also found in other fragmental formations of this region. Underlying the Primordial beds of the Boston and River Parker basins, and having its best development in the towns of Marblehead, Saugus, Melrose, Malden, Medford, Dedham, and Hyde Park, is an extensive and somewhat peculiar conglomerate rock known locally as the "breccia" or "petrosilex breccia," being principally, usually almost wholly, composed of fragments of petrosilex cemented by a paste of the same rock more finely comminuted. The breccia is often of a greenish color, and in not a few localities includes in both fragments and cement large amounts of what appears to be more or less perfect pinite, i. e., material of a light green or greenish-white color, which yields readily to the knife, affords water in the closed tube, and is somewhat unctuous, resembling serpentine in many of its physical characters, and yet easily fusible before the blowpipe. Dr. T. Sterry Hunt has called my attention to the existence of pinite in the breccia in Saugus; and my own observations have convinced me that its occurrence in this way is a general fact. The best points for observing this variety of breccia are the following: East Saugus, south of the railroad; Newton, about one mile south by west from Newton Center; West Dedham; many points in Hyde Park and the adjacent part of Dorchester (Mattapan); and Milton, between the Neponset River and Pine Tree Brook.

The basins mentioned as holding the Primordial strata and the underlying breccia have been excavated from the ancient Huronian formation, which, in Eastern Massachusetts, consists mainly of the following lithological members: granite, binary and hornblendic; petrosilex, stratified and unstratified; stratified and unstratified diorite; and quartzite. In these old crystalline rocks we have the sources of all the materials observed in the conglomerate and breccia, not excepting the pinite. In this connection, the most interesting Huronian terrane is the petrosilex. For the sake of convenience, I here include under the name petrosilex both the acidic division of the compact feldspar rocks, or petrosilex proper, and the basic division, or true felsite. The physical distinctions between the true petrosilex and felsite, in Eastern Massachusetts, are not conspicuous. They both include exotic and indigenous varieties; and both present the same general range in textures, including, besides the ordinary compact and porphyritic forms, many different kinds of banded structure. Elvanite or quartz porphyry is a common rock; but this belongs, of course, entirely to the acidic group. As a result of numerous chemical analyses, I find that the petrosilex predominates, and is usually of red, brown or purplish tints; while the characteristic colors of the felsite are greenish, whitish and sometimes black.

Although associated with both the petrosilex and felsite, the pinite is found most frequently with the latter. Wherever occurring in the conglomerate and breccia, as already observed, this material is always clearly an imported constituent; but with the Huronian formation it never presents this aspect, all the facts pointing to the conclusion that it is indigenous here. In other words, and more explicitly, the pinite, as far as the evidence allows us to judge, exists in the Huronian series only in association with the petrosiliceous group, and here only as a product of the superficial decomposition or alteration of these rocks. Indications of this may be observed in many places. In the first place, we have abundant evidence in the fragmental rocks themselves that the pinite which they contain has been derived from, and owes its genesis to the alteration of, the Huronian petrosilex (using this term in its comprehensive sense, as explained above); for there exists, both in the pebbles of the puddingstone and the fragments of the breccia, every possible gradation between unaltered petrosilex and the purest pinite; and it seems highly probable that much of the petrosiliceous débris of these rocks is still suffering some change in the direction of a conversion to pinite.

Turning now to the parent formation, we find the evidence even more conclusive. For instance, the greenish elvanite which covers a large area in Needham, usually presents a slaty appearance, yields to the knife, and affords water abundantly. Substantially the same statement may be repeated concerning the green petrosilex in West Dedham, and the greenish "toadstone" and some other varieties of petrosilex in Newbury. In all these cases the rock is green, at least superficially. In Marblehead, Lynn, and other districts, I have observed the brown, gray, black, and other colors of the petrosilex changing to green near the joints. In many instances, probably, the change is to kaolinite rather than pinite, but not always.

Another argument showing the derivation of the pinite in the fragmental rocks from the petrosilex is found in the fact that, with few exceptions, those portions of the conglomerate (and the same is true of the breccia), marked by a predominance of pinite débris occur in close proximity to ledges of petrosilex; and in the exceptional cases the underlying rocks are probably petro-siliceous. This association is very significant; but the strongest evidence on all these points yet remains to be adduced.

The locality affording at once the clearest proof that the pinite is indigenous in the petrosilex, that it makes its appearance in this association as a decomposition product, and that pinite so originating is essentially identical with, and the source of, that in the more recent, detrital formations of Eastern Mas-

sachusetts, is in Milton, on Central Avenue, about one-fourth mile south of the Neponset River. The petrosilex is exposed here only on the northwest side of the avenue, forming the southwest end of a section which is composed mainly of a typical example of pinite conglomerate. The small pinite pebbles are embedded in a brownish, slaty paste, and have suffered an extraordinary degree of compression, developing a well-marked foliation or cleavage in the rock. The contact between the petrosilex and conglomerate is straight and well-defined. It strikes east-west, and dips to the north 75°, being exactly parallel with the schistosity or cleavage of the last named rock; while this imperfect cleavage agrees perfectly in dip and strike with that observed elsewhere among the slates and conglomerates of the Boston basin. The contact just noticed almost certainly marks a fault, and both it and the cleavage are at right angles to the strike of the beds. The stratification, however, is much obscured by the cleavage, though it can still be made out by careful observation.

The color of the unaltered petrosilex in this case is dark purple, and the pea-green pinite occurs in it in the form of irregular and ill-defined masses which seem to have their major axes normal to the surface of the ledge. Closer observation shows that they follow the jointing of the petrosilex; each joint being bordered on either side by pinite which exhibits a *gradual* passage into normal petrosilex at a distance of a few inches. The rather limited exposure is best in the vertical direction; and tracing one of the pinite-bordered joints downward, it seems plain that the zone of this material is broadest and best-marked near the surface, becoming narrower below, and almost entirely fading out at a depth of a few feet. The best examples of the pinite are found along those joints which have become the seats of slender veins of quartz. The disposition of the pinite in the petrosilex evidently leaves us no option but to believe that here at least it is a decomposition-product; and that percolating atmospheric water, for which the joints have afforded channels, has been the chief agent in its formation.

The indications are very strong that, geologically speaking, the conglomerate has not been long removed from this part of the petrosilex; hence this is probably, in all essential respects, an ancient surface; and I take it that we have here an example of pre-Primordial decomposition. The composition of a characteristic specimen of the pinite, taken from its original position in this ledge, is shown by the following analysis (I), made by Miss E. M. Walton:—

	I.	II.
SiO_2	57·924	59·520
Al_2O_3	23·739	21·628
FeO	2·826	5·840
K_2O	4·560	6·900
Na_2O	5·283	·804
H_2O	3·142	3·490
MnO	1·443	not det.
Cr and Mg	traces	not det.
	98·917	98·182

The pinite in this petrosilex is unquestionably the source of that with which the overlying slaty and schistose conglomerate is so replete. For, first, the pinite in the conglomerate diminishes rapidly as we recede from the outcrops of petrosilex; and, secondly, the mineral, in the two geological positions, is essentially identical physically and chemically. The pinite pebbles are mostly quite small and well flattened; and hence considerable samples are not easily secured. The portion submitted to analysis was obtained from perhaps a dozen pebbles from different parts of the ledge, great care being taken to prevent admixture with the slaty paste. This was analyzed by Mrs. Alice B. Crosby, and the result is given in analysis II above.*

The formation of pinite by the alteration, and particularly by the hydration, of feldspathic rocks and minerals, which has been denied by some authorities, must apparently be conceded in some cases. Of course where derived from a rock holding free quartz in an impalpable state, such as petrosilex, the pinite, though appearing quite pure, may, as the above analyses show, afford an abnormally high percentage of silica. A typical example of purple banded petrosilex from the Milton area, though not from the pinite ledge, afforded 66·3 per cent of silica. This is, strictly speaking, essentially a true felsite. Other ledges in the vicinity of Central Avenue contain an abundance of pinite, but the exposures are not favorable for displaying its relations to the felsite.

In summarizing the geological history of the pinite (or pinite schist, since, considering its origin, it is rather more properly a rock than a mineral), we may say that, to furnish the pinite detritus of the various fragmental rocks in Eastern Massachusetts, an extensive formation has been required. No vestiges of such a formation, distinct from the Huronian petrosilex, now exist in this region; and with the petrosilex we have the pinite only as a product of superficial decomposition. The facts seem to warrant, or at least to forcibly suggest, the con-

* Both of these analyses were made in the Woman's Laboratory of the Massachusetts Institute of Technology.

clusion that, in pre-Primordial times, the petro-siliceous rocks, to a considerable depth, were changed by the action of atmospheric agents, not to kaolin, as generally at the present time, but to or toward pinite; and that subsequently this decomposition-product was, for the most part, swept away by the sea in which were deposited the breccia and the Primordial conglomerate.

Another very clear example of the derivation of pinite from feldspar has been observed on the rocky peninsula of Marblehead Neck. On the northwest shore of the Neck, visible only at low tide, is a hard, whitish, compact, feldspathic sandstone or slate, the age of which is unknown. It rests unconformably upon the banded petrosilex forming the shore at this point; and the layer of pebbles at its base shows very clearly that the sandstone is chiefly composed of the débris of the petrosilex. This origin explains the highly feldspathic nature of the sandstone. Scattered through the sandstone are clear, almost transparent, rhombic crystals of orthoclase, 3 to 6^{mm} long, which are very clearly indigenous in their present positions. Occasionally they are sufficiently numerous to give a porphyritic aspect to the rock. Erratics of this sandstone are scattered all over the Neck; and in some of these which are very thoroughly weathered, the orthoclase crystals are changed to a soft, unctuous, waxy, green mineral,—in other words, to pinite. Where the weathering has been less thorough, the characters of the pinite are less strongly marked.

ART. XV.—*On Lintonite and other forms of Thomsonite: A preliminary notice of the Zeolites of the vicinity of Grand Marais, Cook County, Minnesota;* by S. F. PECKHAM and C. W. HALL.

GRAND MARAIS is situated on the northwest coast of Lake Superior, one hundred and eight miles northeast of Duluth. It is the site of an early French trading or mission station, and was later a station of the Hudson Bay Company. Its beautiful land-locked bay furnishes the only good harbor between Duluth and Pigeon Point.

The rocks, for several miles east and west, as well as at the Marais, are classed in general as igneous, and have often a basaltic structure. They present, however, great diversities of character both to the chemist and lithologist; and while the mineral species are perhaps altogether old, the forms are in some cases new. It was our original intention to confine this research to one or two peculiar forms that first attracted our attention, but in the progress of our examination the subject has outgrown its

earlier proportions, both as regards its extent and the time required for its successful completion. We have therefore concluded to give in the present paper some general observations with such details as are at present in hand, reserving others until further study and analyses shall have rendered the work more complete.

At Good Harbor Bay, about four miles to the westward of Grand Marais, there begins a bed of dark colored rock, highly decomposed at surface, and related to diabase in its lithological characters. This bed extends westward along the coast for several miles, sloping gently from the wooded hilltops a mile or two inland, and disappearing beneath the waters of the lake. In its fresher parts the rock is somewhat mottled where coarsest, and nearly black with a greenish tinge where finest in texture. It is only from the talus, under the wall of rock rising above an underlying sandstone outcrop in Good Harbor Bay, that this fresh material can be easily obtained. Even here the mottled appearance discloses the partial decomposition of the most perishable of the constituents, and the formation of some new viriditic mineral. The lower layers are firm and compact, while the upper are extensively jointed and fractured, and filled with amygdaloidal cavities. These cavities, in whatever manner they were originally formed, have become filled with zeolitic minerals. Some of the cavities are now empty, but evidently as a result of the removal of their contents by solvents percolating through the enclosing rock. Occasionally the cavities are only partially filled, and the substance within shows on its surface unmistakable traces of the action of solvents. In some cavities one mineral is nearly all washed away, leaving the surface of the remaining one or several, as the case may be, rough or uneven, as originally formed. This occurs only where water has had access.

The prevailing mineral, thomsonite, is only sparsely distributed in the lower and compacter beds of the formation. The general occurrence of the several other minerals, so abundant here, would seem to indicate that this mineral was formed first of all from the decomposition of the rock, and that one of the others owes its origin in part at least to the decomposition of those that were formed before it. In many masses of the rock where much exposed and weathered the matrix has been so decomposed as to be easily broken away from the amygdules, but in the fresher portions the fractures extend across them. The other zeolites, being less persistent than the thomsonite, rapidly disappear, while the amygdules of this mineral remain upon the narrow beaches of this vicinity in the form of pebbles of various sizes frequently unbroken and beautifully polished.

The cavities containing thomsonite are in many places ex-

ceedingly numerous, and in other cases few in number, even in the same bed of rock. The size varies from a microscopic point to a diameter of two or three inches. In one piece of the thomsonite-bearing rock, now in the General Museum of the University of Minnesota, the number of amygdules distinctly visible to the unaided eye on a surface two inches square is sufficient to give more than 10,000,000 to the cubic foot. The largest in this area was about half an inch in diameter. The amygdules are generally much larger and more scattered than this specimen would indicate. Since they abound in the rock throughout many feet of its thickness and many miles of its extent along the shore, the supply appears to be inexhaustible; but practically the number of beach-pebbles, valuable as specimens, is quite limited. All the different varieties of thomsonite are so hard that they take a fine polish; and on account of this property and their often unique banded structure, they are much sought after by tourists and others as objects of rare beauty, and also for buttons, studs, etc.

On our first visit to the beach where the greater number of these pebbles occur, we at once recognized fragments of the large amygdules as thomsonite. Intermingled with these were spherical and oval pebbles, often more or less flattened, and of all sizes from that of a pin's head to that of a hickory nut, but for the most part of the size and form of beans and peas. Some of these were also recognized as thomsonite. The larger portion presented a great diversity of color and physical structure; some being white and opaque, almost conchoidal in fracture, with but slight indications of a fibrous structure; others flesh-colored throughout, hard and fibrous, resembling thomsonite from the Tyrol and other localities except in their greater hardness and finer texture; others coarser, closely resembling the mineral from other localities; others, curiously banded externally with zones and annular spaces of red, green, pink and white; and still others, opaque and chrome-green in color, shading out in some to colorless and translucent with a con choidal or uneven fracture. These last were at first supposed to be fragments of prehnite, rounded by attrition. On further examination a number of the green pebbles were found to have a fibrous and flesh-colored interior with a shell of the amorphous green mineral. In given portions of the rock formation, the amygdules were, for the most part, of the same general character; in one place, being green and opaque; in another, without green bands; while in another, for the most part, beautifully variegated. Similar local peculiarities were observed in reference to texture, some portions of the rock containing only those that were hard and fine grained, while others those that were uniformly coarser in texture.

In our examinations of the amygdules, we designated the opaque white variety, Number *one* (I), the ordinary thomsonite, Number *two* (II), and the *green* varieties, Number *three* (III).

As regards hardness, the thomsonite—in nearly all its varieties—is peculiar. Some fibers scratch quartz, which indicates a hardness above 7; but this may be owing to the presence of free silica. The harder specimens of No. III scratched an agate mortar easily, but were scratched by quartz crystal; yet the percentage of silica was found to be no higher in the harder than the other specimens. The grain of such specimens, however, is exceedingly fine. Most frequently the hardness is between 5 and 6. The specific gravity varies from 2·33 to 2·35; the water-worn and somewhat weathered pebbles have it a little lower, one or two as low as 2·2. The fracture of Numbers I and II is fibrous; of Number III very uneven, and takes place in all directions with almost equal facility. They all gelatinize in hydrochloric acid to a thick jelly. Before the blowpipe they fuse easily and intumesce to a porous white enamel. In the closed tube, water to the amount of 11 to 12 per cent of the whole weight was given off at the heat of an ordinary spirit lamp. Grains of native copper are frequently found in them, particularly in those of Number III, which, if the pebbles are transparent, exhibit under a low magnifying power arborescent groups of crystals, thrusting out their branches in every direction through the enclosing mineral. In one instance an amygdule, about as large as a cranberry, contained at its center a mass of copper of this kind, one-third of its diameter. In this characteristic Number III resembles the prehnite of French River.

Number I.—The amygdules of this type are perhaps of less common occurrence than other forms. Externally they look like porcelain with a slight creamy tint. Under the microscope they appear for the most part translucent. Countless fine dark lines extend longitudinally through the thin section, rapidly disappearing to be replaced by others, like the cells in a longitudinal section of wood, which are probably caused in part by refraction of the light from the edges of minute densely packed crystals, from cavities, and from microlites. One noticeable result of these lines is to weaken the effect of the mineral on polarized light. Not infrequently this opaque modification of the mineral is banded with alternating zones, either transparent or yellow, or even with both; the transparency here seems to be owing to an absence of the lines and microlites just noticed; while the yellow zones owe their color to globules of ferric oxide distributed through the mass. In the worn amygdules the mineral often has a beautiful pearly luster. In minute quantities the ferric oxide gives the mineral a flesh-colored tint.

A mean of three analyses showed the composition of this mineral to be:

SiO_2	40·45
Al_2O_3	29·50
Fe_2O_3	0·232
CaO	10·75
K_2O	0·357
Na_2O	4·766
H_2O	13·93
	99·985

Even opaque *white* amygdules afforded a trace of ferric oxide, which increased to a few hundredths of one per cent when the tint was perceptibly flesh-red.

Number II.—Under this type nearly every specimen is fibrous and radiated. The masses are spherical or elliptical, with the point from which the crystalline fibers radiate on one side of the mass, or, as is perhaps more common, having several centers of radiation within the compact mass. Occasionally the mineral fills seams, or occupies cavities that run together; here, there are centers of radiation at frequent intervals and by a system of suture-like joints, the whole is made into a compact mass. Yet, solid as the mass may appear to be, a thin plate cut from it invariably separates into pieces along the line of these joints, giving the mineral an appearance of fragility while it is really as hard as agate. The fibers often interlock along the line of these joints.

At the outer extremity of many of these radiated concretions, there often occur many transparent needles, large enough to be seen with the unaided eye, extending backward along the direction of the fibers toward the center of radiation. These needles are broken up into short pieces by transverse fractures. They all taper out and disappear, the longest of them reaching no further than the middle of the mass. They act strongly on polarized light and contain some inclusions. These lines do not occur as developed crystals.

Around the borders of many amygdules there are numerous small sphærolites. They have probably formed around granules of various foreign substances as nuclei. Their size is small; to the naked eye they look like mere spots, but they are so numerous as to form an envelop almost entirely around the radiated concretions.

A mean of three analyses gave—

SiO_2	46·020
Al_2O_3	26·717
Fe_2O_3	0·813
CaO	9·400
K_2O	0·390
Na_2O	3·756
H_2O	12·800
	99·896

Number III.—As before stated these pebbles, when first seen, were supposed by us to be worn fragments of reniform prehnite, so common in several localities along this shore. We soon found evidence that they were amygdules; still the fact that they were not prehnite was not suspected until their specific gravity had been determined and found to be that of thomsonite, 2·32 to 2·37. Analysis showed them to contain—

SiO_2	40·605
Al_2O_3	30·215
FeO	·40
CaO	10·370
K_2O	·49
Na_2O	4·055
H_2O	13·75
	99·885

This composition allies the mineral very closely to thomsonite, so closely that, considered alone, there appears little reason why the mineral should not be considered as a variety; but there are several notable reasons why a specific name may properly be applied to this, as we believe, hitherto undescribed mineral.

These pebbles are wholly destitute of the radiated and crystalline character of other forms of thomsonite. Under the microscope the texture is wholly granular so that the crystalline system cannot be determined; and the granules are so fine and so compactly arranged in many specimens that they can be resolved only in polarized light. Their size, however, is not uniform in the same pebble, being so fine in some places that only a high power will make them visible.

Sphærolites are also frequent; but unlike their mode of occurrence in the thomsonites, they are distributed almost at random in any part of the amygdules containing them; and frequently some foreign material, as a bit of copper, is a nucleus. The sphærolites often occur in groups; large numbers are crowded and heaped together, growing into and overlapping one another, like the tridymite scales in the rhyolites of Mexico and the trachytes of the Siebengebirge. These groupings are not always spherical; sometimes they extend in long curving lines through the mass, following perhaps a fracture or

a seam, instead of being collected around a nucleus as a sphærolite. They show parallel green fibers meeting along a median suture and correspond in their manner of occurrence to Zirkel's description of axiolites in the rhyolites of the 40th parallel.*

The amygdules of the green variety rarely exceed in size a small hickory nut. As before stated, they are not generally found intermingled in the rock with the other forms, but have special localities—they filling nearly all the amygdaloidal cavities within a given limit, whose boundary at the same time is not sharply defined. Frequently the forms of Number I or II are enveloped in a green covering of considerable thickness. Moreover, the amygdules of this type uniformly contain ferrous oxide in small but varying proportion in combination, whereas in Numbers I and II the microscopic sections show the ferric oxide to be segregated in minute particles or patches mechanically distributed through the fibrous mass; and in many amygdules these particles can be seen distinctly even with the unaided eye. Nor can Numbers I and II be considered as altered forms of Number III, as the condition of the iron might indicate. No amygdule has come under our observation which exhibited a nucleus of Number III, surrounded by Number I or II. On the contrary, we have quite a number in which, through a thin translucent shell of Number III, the pink interior can be discerned. And we also have fragments, and amygdules have been cut, which show the external crust of Number III passing toward the center into the radiated form of Number II.

In determining the oxygen ratio for Number II, the silica appeared to be too high. We had previously suspected the presence of free silica from the exceptional hardness of all of these varieties. As the microscope showed the ferric oxide in every case to be free, we concluded to compute the percentages for Number II to 40·45 per cent of silica, the amount found in Number I, and exclude the iron oxides. We were much surprised at the results, which are given below:

	I.	II.	III.
SiO_2	40·45	40·45	40·605
Al_2O_3	29·50	29·37	30·215
CaO	10·75	10·43	10·37
K_2O	0·36	0·42	0·49
Na_2O	4·76	4·28	4·05
H_2O	13·93	13·93	13·75
	99·75	98·88	99·48
Fe_2O_3	0·23	0·88	FeO ·40
	99·98 pr. ct.	99·76 pr. ct.	99·88 pr. ct.

* U. S. Geol. Explor. 40th Parallel, vol. vi, p. 166 et seq.

These figures prove conclusively that we were dealing with varieties of the same mineral. On comparing these percentages with those given in Dana,* the water and silica were found to be high.

Computing the oxygen ratios and formula for Number III, we have

	Per cent.	Metal.	Oxygen.	Atoms.
FeO	0·40	0·3111	0·0889	·0064
K_2O	0·49	0·4068	0·0832	·0052
Na_2O	4·055	3·0118	1·0432	·0654
CaO	10·37	7·4070	2·9630	·1852
			4·1783 R.	·2622
Al_2O_3	30·215	16·1343	14·0807	·2933
SiO_2	40·605	18·949	21·656	·676
H_2O	13·75	1·528	12·222	·765

Dividing the oxygen percentages by 5, we have

$$RO : R_2O_3 : SiO_2 : H_2O = 1 : 3 : 4 : 2\tfrac{1}{2},$$

which is the ratio for thomsonite, given in Dana's Mineralogy, with the bases low and the silica and water high. Dividing the atoms by ·005 we have the formula

$$(\tfrac{2}{5}(FeO+K_2O+Na_2O)+\tfrac{3}{5}CaO)Al_2O_3, (SiO_2)_2(H_2O)_2,$$

with the protoxide bases low, and the silica and water high.†

Computing the ratios after Rammelsberg, we have:

$$(Na+K) : (Ca+Fe) :: 1 : 1·35$$
$$(Ca+Fe) : Al :: 1 : 1·54$$
$$(Ca+Fe+K+Na)=R : Al : Si :: 1·13 : 1 : 2·03$$
$$Si : H :: 1 : 2·26$$

Rammelsberg deduces from these ratios a formula which he calls a half silicate (Halbsilicat), according to the expression

$$\left\{ \begin{matrix} m(2Ca\ AlSi_2O_6+5aq) \\ n(2Na_2AlSi_2O_6+5aq) \end{matrix} \right\} ‡$$

in which m indicates a certain proportion of a hydrous silicate of aluminum and a dyad protoxide, and n a certain proportion of a hydrous silicate of aluminum and an alkaline or monad protoxide. The ratio between m and n varies in different specimens. Number I and Number II, without the excess of silica, approach more nearly the thomsonite of Elbogen in composition (in which the ratio of m to $n=2:1$) than any mentioned by Rammelsberg. While the ratio of Si to H is about the same as given by Rammelsberg, the percentage of both in these specimens is higher than in the analyses quoted by him.

* System of Mineralogy, fifth edition, p. 425.
† 5th ed., p. 425.
‡ Rammelsberg Min. Chem., Ed. 1875, p. 637.

We conclude, therefore, that this mineral contains a small percentage of free silica, and also that a part of the water is basic. This latter opinion is strengthened by the fact that about 12 per cent of the water escaped at a dull red heat, and that only prolonged heating in a platinum crucible for several hours would expel the last 1·75 per cent. At least six determinations of the water were made in this variety, with the same result.

The percentages of Numbers I and II are so near that of Number III that no material difference can exist in their formulæ. While recognizing this fact as respects the chemical constitution of these minerals, the great difference in their physical structure leads us to regard Number III as a distinct and well marked variety of thomsonite, if not a distinct species. We have therefore given it the name *Lintonite*, in honor of Miss Laura A. Linton, a recent student and graduate of this University, to whose patient effort and skill we are indebted for the analyses given in this paper.

University of Minnesota, Nov. 20, 1879.

ART. XVI.—*Elements of the Planet Dido;* by Professor C. H. F. PETERS. (From a communication to the Editors, dated Litchfield Observatory of Hamilton College, Clinton, N. Y., January 4, 1880.)

FOR the planet *Dido* (209), I have derived from observations of October 25, November 15 and December 7, the following elements:

Epoch: 1880, January 0·0, Berlin m. t.

$$\begin{aligned} M &= 201^\circ\ 56'\ 40''.3 \\ \pi &= 196\ \ 41\ \ 13.6 \\ \Omega &= \ \ 1\ \ 21\ \ 41.3 \\ i &= \ \ 7\ \ \ 3\ \ \ 9.0 \\ \phi &= \ \ 1\ \ 18\ \ 38.3 \\ \mu &= 629''.122 \\ \log a &= 0.500848, \end{aligned}$$

which represent an observation obtained on January 1, when it was still very near. The small eccentricity of the orbit is remarkable. In consequence of this, there remains considerable uncertainty as to the longitude of perihelion and the mean anomaly, but not as to their sum $M+\pi=L$, the mean longitude in orbit.

ART. XVII.—*Analyses of some American Tantalates;* by W. J. COMSTOCK. (Contributions from the Laboratory of the Sheffield Scientific School, No. LVII.)

THE following paper contains analyses of three American tantalates which have not been previously investigated, and which offer some points of especial interest.

No. I was collected by the late Professor F. H. Bradley, in Yancey county, N. C.; its precise locality is unknown. The specimen analyzed was from a massive piece, a few ounces in weight. Specific gravity = 6·88.

	I.	II.	Mean.	Ratios.	
Ta_2O_5	60·50	59·35	59·92	·1349	·2231
Nb_2O_5	23·02	24·24	23·63	·0882	
FeO	12·90	12·82	12·86	·1786	
MnO	3·09	3·03	3·06	·0431	·2302
MgO	0·35	0·32	0·34	·0085	
Total	99·86	99·76	99·81		

$R_2O_5 : RO = 1 : 1·03$ and $Nb_2O_5 : Ta_2O_5 = 1 : 1·53$ or nearly 2 : 3.

No. II was from Northfield, Mass. The portion analyzed was a fragment of a large crystal, which had the habit and angles of ordinary columbite. It was placed in my hands by Professor Brush. Specific gravity =6·84.

	I.	II.	Mean.	Ratios.	
Ta_2O_5	57·23	56·57	56·90	·1281	·2281
Nb_2O_5	26·62	27·01	26·81	·1000	
FeO	10·11	9·98	10·05	·1397	·2225
MnO	5·92	5·85	5·88	·0828	
Total,	99·88	99·41	99·64		

$R_2O_5 : RO = 1·025 : 1$ and $Nb_2O_5 : Ta_2O_5 = 4 : 5·1$.

No. III was from Branchville, Conn. Its occurrence was described by Messrs. Brush and Dana,* and the specimen analyzed was given to me by them. Only a small quantity of the mineral was found at the locality, and enough for one analysis was all that could be obtained pure. Its powder was brownish-gray, and in thin fragments it was slightly translucent. Specific gravity =6·59.

		Ratios.	
Ta_2O_5	52·29	·1175	·2301
Nb_2O_5	30·16	·1126	
MnO	15·58	·2194	
FeO	0·43	·0059	·2319
CaO	0·37	·0066	
Total,	98·83		

$R_2O_5 : RO = 1 : 1·007$ and $Nb_2O_5 : Ta_2O_5 = 1 : 1·04$.

Tantalic and niobic acids were separated by Marignac's method,† in the application of which I have received all neces-

* This Journal, July, 1878, p. 34. The specific gravity, by a typographical error, as I am informed, is there given 5·6 instead of 6·5.

† Archives des Sci. Phys. et Nat., Jan., 1866.

sary aid from Professor O. D. Allen. In other respects the methods recommended by H. Rose were followed. The ordinary methods of testing for and separating tin, tungsten and titanium were applied in each case, with negative results.

The relation between the specific gravities of columbites and tantalites and the percentage of tantalic acid, shown by Marignac, holds good in these examples also, as will be seen by a comparison with the numbers given in Marignac's table.*

		Sp. gr.	Ta_2O_5.
1.	Columbite, Greenland,	5·36	3·3 %
2.	" Acworth, N. H.,	5·65	15·8
3.	" La Valate, near Limoges,	5·70	13·8
4.	" Bodenmais, (*Dianite*),	5·74	13·4
5.	" Haddam, Conn.,	5·85	10·(?)
6.	" Bodenmais,	5·92	27·1
7.	" Haddam,	6·05	30·4
8.	" Bodenmais,	6·06	35·4
9.	" Haddam,	6·13	31·5
10.	Tantalite,	7·03	65·6

To which are here added—

	Sp. gr.	Ta_2O_5.
Yancey Co, N. C.,	6·88	59·92
Northfield, Mass.,	6·84	56·90
Branchville, Conn.,	6·59	52·29

These all agree with the formula $(Fe,Mn)(Ta,Nb)_2O_6$.

Since tantalum and niobium appear capable of replacing each other in all proportions in columbites and tantalites, Rammelsberg† has suggested that when the number of tantalum atoms exceeds that of the niobium atoms, the mineral should be called tantalite, and when the number of niobium atoms exceeds that of the tantalum, the mineral should be called columbite (Rammelsberg uses *niobite*). According to this method of classification, the Yancey county and Northfield minerals would be called tantalite, although the latter in form is not to be distinguished from columbite. The manganese niobo-tantalate from Branchville, however, has the ratio $Nb : Ta = 1 : 1$ (very nearly), a coincidence which we might reasonably have supposed possible. The almost complete displacement of iron by manganese is also an interesting peculiarity of the Branchville mineral, and is doubtless the cause of its slight translucency and the light color of its powder.

It is perhaps of interest to add here that a mineral of this group from Utö, Sweden, containing 85·5 per cent of tantalic and niobic acids and 9·5 per cent of manganese protoxide (3·6 FeO), has been called *mangantantalite* by Nordenskiöld.‡

* Given in his paper first referred to, in which he explains the variations from a regular progression, which are seen in the table.

† Mineral Chemie, 2d edition, 1875, p. 356. ‡ Zeitsch. Kryst., i, p. 386, 1877.

ART. XVIII.—*On a Method of Studying the Reflexion of Sound-Waves;* by O. N. ROOD, Professor of Physics in Columbia College.

IT has been the custom for several years to introduce in certain forms of the melodeon a revolving fan for the purpose of obtaining rapid alternations in the intensity of the notes. This arrangement is called a "tremolo," and its action was considered by its inventor and by those interested in it to depend on the currents of air produced by the motion of the fan. An examination of the apparatus soon convinced me that this idea was erroneous, and that the alternations in the loudness of the sound was due to reflexion or non-reflexion from the face of the revolving fan, for I found that the same effects could be produced by the aid of a circular disc consisting of open and closed sectors and revolving in its own plane. A disc of this kind constitutes a useful piece of apparatus for studying the reflexion of sound-waves, and some results obtained with it were communicated by me to the National Academy of Sciences, as long ago as October, 1876.

As no account of these experiments has ever been published, a short description of them may not be without interest to those engaged in experimental researches on sound, as with their aid the following facts may be easily demonstrated:

1*st. At a perpendicular incidence the short sound-waves are more copiously reflected than those that are longer, and the regular reflexion is more copious from large than from small surfaces.*

The diameter of the zinc disc was in the first set of experiments 21 inches =53·3 centimeters; alternate quadrants were removed, and the rate of rotation varied from two to four turns in a second. The tuning-forks were mounted on their resonance boxes and gradually removed away from the revolving disc till the alternations could no longer be distinguished by the ear placed near the fork. The results are given in the table below, in which "distance" indicates that of the open end of the tuning-fork from the disc:

Diameter of disc			21	inches.	
Ut_3 fork;	alternations heard at		13	"	distance.
Ut_4 "	"	"	20	"	"
Ut_5 "	"	"	96	"	"

When the same experiments were made with a disc having a diameter of only $8\frac{1}{2}$ inches or 21·5 centimeters, it was found necessary to bring the forks much nearer to the disc before the alternations could be perceived.

Diameter of disc			$8\frac{1}{2}$	inches.	
Ut_3 fork;	alternations	heard at	2	"	distance.
Ut_4 "	"	"	3	"	"
Ut_5 "	"	"	6	"	"

2*d*. *When the sound-waves fall upon small flat surfaces at an acute angle, the reflexion is most copious in the same direction as with light, but the reflected and inflected waves can be traced all around the semicircle.*

Experiments on this point were made in the open air, the larger disc being used with angles of 60° and 70° (from the perpendicular); the Ut_4 and Ut_5 forks were employed.

The regularly reflected waves could be heard at a distance of ten or twenty feet from the disc, the fork being held a foot or two from it; inflected waves were easily distinguishable all around the disc and even a few feet *behind* the fork.

When the forks were placed in the plane of the disc the alternations of loudness were reduced to a minimum, but in the open air and in a room never wholly disappeared. This I suppose to be owing to the fact that the source of sound is not a point but a surface. Even under these circumstances, feeble alternations were heard all around the disc, the inflected waves actually returning to their source. With a plain disc alternations were not perceived.

3*d*. *Qualitative comparisons between the power of different substances to reflect sound can easily be made.*

For example, a disc of card-board in which filter paper is fastened over the open sectors gives alternations, owing to the difference of the reflective powers of the two substances.

4*th*. *If a composite sound-wave falls on the rotating disc the shorter waves will undergo regular reflexion more copiously than the other components.*

This experiment is most easily made with a reed without its pipe. Ut_3, Ut_4, Ut_5 reeds give alternations but mainly in their high overtones; the alternations consequently have a ringing metallic sound.

5*th*. *The reflexion of sound from very small surfaces is easily demonstrated.*

If an Ut_3 or Ut_4 reed without its pipe be employed, alternations are easily obtained by moving a visiting card properly near the reed. By substituting a gas-flame for the card the reflexion from the flame can be demonstrated. The gas-burner should be attached to a long slender rod.

Almost all of these experiments are so easily performed as to be suitable for lecture-room purposes.

ART. XIX.—*On Newton's use of the term Indigo with reference to a Color of the Spectrum;* by Professor O. N. ROOD, of Columbia College.

THE coloring matter known as indigo has a dingy, dark blue color, which scarcely qualifies it to rank as a representative of one of the pure brilliant colors of the spectrum. Von Bezold has already objected to its use on account of the *darkness* of the tint, but in the present paper I propose to show that in another and more important respect it is equally inapplicable. Newton intended to designate by it the color of that part of the spectrum which is situated between the blue and violet; indigo, however, is really a representative, though a poor one, of an entirely different region of the spectrum, as will be shown by the following considerations.

Experiments were first made with three different samples of indigo in order to see whether important differences in hue existed when the substance was prepared by different persons. One of the best methods of studying the hue of a colored surface is to ascertain the nature and amount of the colored light which is complementary to it. Discs of card board were accordingly painted with indigo as a water-color pigment and these were combined by Maxwell's method with two discs painted with chrome yellow and vermilion, and neutralization effected by rapid rotation.

Indigo as a water-color pigment (prepared by Winsor and Newton).

Ratio of red and yellow necessary to neutralize it.

Chrome-yellow, 67. Vermilion, 33.

Indigo as a water-color pigment (prepared by Barnard).

Chrome-yellow, 65. Vermilion, 35.

Dry commercial indigo was then rubbed on white drawing paper, and gave a result similar to those just detailed; the ratio was:

Chrome-yellow, 62. Vermilion, 38.

In the dry state the color was then a little more greenish, a slightly larger quantity of the vermilion being required; the three experiments, however, substantially agree.

A solution of commercial indigo in water was also compared with the discs, and seemed to agree well with them.

Instead of comparing one of the dingy indigo discs directly with the brilliant-colored spaces of the spectrum, I made an accurate comparison of its color with that of a disc painted with Prussian blue, reserving the latter for direct comparison with the spectrum.

The Winsor and Newton disc which the previous experiment had proved to be the least greenish in hue, was now combined with one of vermilion and emerald green, and the following equation obtained:

I 51·4+V 29+G 19·6 =32·8 white. A disc of Prussian blue similarly treated gave P.b. 39·9+V 35·7+G 24·4 =27·4 white.

These equations prove that the *hue* of the indigo and Prussian blue discs were identical, for the ratio of the red and green required to effect neutralization is the same, being in the case of the indigo, 59·7 vermilion to 40·3 emerald green; in that of the Prussian blue, 59·4 vermilion to 40·6 emerald green.

The position of the Prussian blue disc in the normal spectrum was now determined with the aid of a large spectrometer, the eye-piece being provided with a slit which excluded all except a narrow slice of the spectrum. Such determinations can be made by a practiced eye with considerable certainty, as I propose to show at some future time. It was found that in a normal spectrum including from A to H 1000 parts the position of Prussian blue was at a distance from A equal to 740 of these parts. Now according to my observations on this spectrum, blue-green ends and cyan-blue begins at 698; also cyan-blue ends and blue begins at 749; hence the color of Prussian blue falls in the cyan-blue space near the beginning of the blue, and to this same position we must consequently refer the color of indigo.

It afterwards occurred to me that possibly Newton might have used the indigo in the dry lump, and accordingly I prepared a flat surface of dry commercial indigo and compared it carefully with the blue furnished by genuine and artificial ultramarine, its color being of course enormously darker, or one might say, blacker than that of either of these substances. A mixture by rotation of six parts of artificial ultramarine blue with two parts white and ninety-two parts black gives a color more or less like that of commercial indigo in the dry cake: that is to say, if a freshly *fractured* surface of indigo be compared with the compound disc just mentioned, the color of the indigo will be found somewhat too greenish; but on the other hand, if a *scraped* surface of the dry cake is used it will be too purplish. Newton therefore probably employed his indigo in the dry state.

I give below, according to my determinations, the positions and corresponding wave-lengths of indigo, Prussian blue, cobalt-blue, genuine ultramarine-blue and artificial ultramarine-blue, in a normal spectrum having from A to H 1000 parts.

	Position in normal spectrum.	Wave-length in $\frac{1}{10000000}$ mm.
Indigo, Prussian blue,	740	4899
Cobalt-blue,	770	4790
Ultramarine (genuine),	785	4735
Ultramarine (artificial),	857	4472

It has been shown then,

1st. That the color of indigo is really a greenish blue when it is used as a pigment or in solution.

2d. The color of the dry cake is not only very black, but variable according to the mode in which it is handled.

Taking all this into consideration, it would appear desirable to allow the term indigo to fall into disuse, and to substitute for it ultramarine, the color of the artificial variety being intended.

ART. XIX.—*Notice of recent Additions to the Marine Fauna of the Eastern Coast of North America, No.* 8; by A. E. VERRILL. *Brief Contributions to Zoology from the Museum of Yale College.* No. XLV.

CEPHALOPODA.

Octopus obesus, sp. nov.

Male, remarkable for the great size of the spoon-shaped organ of the right arm of the third pair. Body relatively large, stout, oblong-oval, somewhat flattened above, obtusely rounded at the posterior end; soft and somewhat gelatinous in texture; skin, so far as preserved, smooth, soft. No cirrus exists above the eye, in our specimen, but the skin is not well preserved in that region. Eyes very large. Arms moderately long, the dorsal longest, others successively shorter; all somewhat laterally compressed at base, tapering to long, slender tips; a moderately developed web connects them together at base. The hectocotylized arm (third of right side), bears at the end a very large, broad and thick, but not very deep, spoon-like organ; its inner surface is crossed by eleven oblique, thick, rounded folds or ribs, ten of them converging backward to the median line and at their outer ends joining a marginal thickening; the distal end terminates in a median pointed lobe, with a thin, rounded, lateral lobe each side of it; the proximal border is formed by the last (eleventh) fold, which is V-shaped, with the apex pointing distally. A broad thin marginal membrane extends along the lower side of the arm, from the terminal organ to the base. The suckers have been partly detached from this arm. Suckers of all the arms moderately large, nearly globular

in form, rather numerous; the first six to ten from the base are nearly in one line, except on the left arm of second pair, and appear to form only a single row; in this part the inner face of the arm is narrow, and most so on the right arm of the second pair, and least on the left of the same pair; farther out this face becomes broader and the suckers are in two distinct rows; they are destroyed on the distal portion of all the arms. Color of body and arms mostly destroyed, but so far as preserved, pale pinkish, more or less thickly speckled with distinct reddish brown spots, most conspicuous at the bases of the arms and above the eyes (elsewhere the color is probably not so well preserved). Length of body, from posterior end to base of arms, 82^{mm}; to center of eye, 72^{mm}; to edge of mantle, beneath, 49^{mm}; to tip of right dorsal arm, 213^{mm}: left, 198; to tips of second pair, 200; to tip of right arm of third pair, 173; of left, 197; to tip of right of fourth pair, 187; of left, 178; to edge of web, 110; breadth of body, in middle, 46; breadth of head, across eyes, 38; breadth of dorsal arms, at base, 8^{mm}; diameter of largest suckers, 3^{mm}; length of spoon-shaped end of right arm of third pair (hectocotylized), 35; breadth, 16; length of rest of arm, to mouth, 65^{mm}.

Taken from the stomach of a halibut, 36 miles east from the N. E. Light of Sable Island, in 160 to 300 fathoms, by Charles Ruckley, of the schooner "H. A. Duncan," and presented by him to the U. S. Fish Commission, 1879.

This species differs from *Octopus Bairdii* V.,* and *O. piscatorum* V., from the same region, in its longer and larger body, and especially in having the basal suckers in a single row. The 'spoon' of the hectocotylized arm is much larger than in *O. Grönlandicus*, and larger and flatter than in *O. Bairdii*.

***Octopus lentus*, sp. nov.**

Female, body broad, stout, depressed, slightly emarginate at the posterior end, soft to the touch and somewhat gelatinous in appearance; a thin, soft, free, marginal membrane runs along the sides and around the posterior end of the body, becoming widest (about 12^{mm}) posteriorly. Head large, broad, depressed, with the eyes large and far apart; above each eye there is a small, simple, conical, acute cirrus. A well-developed, thin web connects the arms, considerably above their bases, and then

* Although only males of this species were originally described, we have since taken large numbers of both males and females. The sexes differ but slightly, except in the hectocotylized arm of the male. The sexes apparently do not differ to any great extent in size. A second female specimen of *O. piscatorum* V. has also been received. It was taken by Capt. David Campbell and crew, of the sch. "Admiral," on the Grand Bank, N. lat. 44° 07′; W. long. 52° 40′, in 200 fathoms, December, 1879. It is nearest allied to *O. Grönlandicus*, (of which the males, alone, are known to me) and may prove to be only the female of the latter.

runs up to the tips as a broad margin to each arm. The arms are rather large, stout at base, with broad inner face, gradually tapering to very slender tips; the first and third pairs are nearly equal in length; those of the second are also about equal in length to the fourth pair, but are somewhat shorter than the first and third. The arms on the right side are all somewhat longer than the corresponding ones on the left. The arms, measuring from the beak, are more than twice as long as the body. The suckers are arranged in two distinct rows, to the base. Color of head and body, above, and of body, beneath, deep reddish-brown, closely specked with darker brown, and with many small roundish spots of whitish on the body and arms.

Length, beak to end of body, not including marginal web, 60^{mm}; breadth of web, 22^{mm}; length of longest arms of right side, 1·12^{mm}; total length, 194^{mm}; breadth of body, 40^{mm}; breadth of head, across eyes, 32^{mm}; of eye-openings, 10^{mm}; of eye-balls, 17^{mm}; length of mantle, beneath, 38^{mm}; length of first pair of arms, 112 and 105^{mm}; of second pair, 103 and 96^{mm}; of third pair, 112 and 106^{mm}; of fourth pair, 94 and 97^{mm}; breadth of those of the three upper pairs, 8^{mm}; of the ventral pair, 7^{mm}. Taken off Nova Scotia, near Le Have Bank, in 120 fathoms, by Captain Samuel Peeples and crew of the schooner "M. H. Perkins," and presented to the U. S. Fish Commission.

In the soft consistency of the flesh and skin this species resembles the preceding. The shorter and posteriorly emarginate body, and especially the great difference in the arrangement of the suckers, render it very improbable that it is the female of that species.

Echinodermata.

Brisinga Americana, sp. nov.

A large and very showy species with fifteen to twenty long and very spinose rays, which are high and much compressed laterally near the base, but farther out become depressed and taper gradually to the slender ends. In our specimen the disk is gone. Fifteen detached arms remain; some of them entire, but mostly broken, probably by the spontaneous contractions of the creature when taken. According to the statement of the captors it had twenty rays, originally. The longest rays, as preserved in strong alcohol, are 353^{mm} (14 inches) long; greatest height (about 1·5 inches from base) 32^{mm} (1·26 inches), not including spines; transverse diameter at same place, 16 to 19^{mm} (·65 to ·75 inch); transverse diameter at about the middle, exclusive of spines, 10 to 12^{mm}; height, 7^{mm}. The adambulacral plates bear a simple row of slender, acute spines, one to

each plate; they are comparatively short near the base of the arms, but soon become much longer and more slender, and so continue to near the end. Just outside of these, on each side, along most of the arm, there are transverse clusters of four or five very long, slender, acute, divergent spines, borne upon transverse prominent lateral plates, one of which occurs opposite about every fourth adambulacral plate; toward the base of the arms these clusters become gradually reduced, both in number and length of the spines, till two small ones remain, and finally only one; and still nearer the base, for about an inch, this disappears also, leaving the broad side, close to the swollen base naked of spines, except dorsally; the elevated basal region, except close to base, is crossed by series of transverse lateral and dorsal plates, in line with those described, and forming prominent ridges, which bear long, slender, sharp spines, in simple, transverse series; between these ribs the skin is naked and there are numerous slender scattered papulæ. The transverse rows of dorsal spines continue to or beyond the elevated region of the ray (nearly one-third of the length); beyond this the dorsal surface is covered with low, granular verrucæ, to the end. All the spines are enclosed, when perfect, by a loose, bag-like membrane, extending beyond their tips, and covered with minute pedicellariæ, granule-like in size and appearance, like those of the dorsal verrucæ. The ambulacral suckers are large and form two regular rows. Eyes, in alcohol, yellowish, well-developed. Length of adambulacral spines, at base of arm, 5^{mm}; in middle of arm, 8^{mm}; length of longest lateral spines, along middle of arm, 12 to 14^{mm}; including the sac, 16^{mm}. Color, pale orange-red, in alcohol, when first received, soon fading to whitish; when living probably bright red.

Taken off Nova Scotia, on the western part of Banquereau, in 175 fathoms, by Captain Samuel Peeples and crew, of the schooner "Addison Center," and presented to the U. S. Fish Commission.

This species is related to *B. coronata* G. O. Sars, but it has much larger and stouter arms, and much larger adambulacral spines, and more numerous lateral and dorsal ones. Our specimen was found clinging to the branches of *Paragorgia arborea.*

ART. XX.—*The Electric Light;* by F. E. NIPHER.

IN the Philosophical Magazine for January, 1879, p. 30, Mr. W. H. Preece gives a discussion, in which he shows the condition to be supplied in electric lighting, in order to obtain a maximum effect. In eq. 2, p. 31, he gives for the heat distributed to the incandescent material,

$$H = \frac{E^2 l}{(\rho + r + l)^2}$$

where ρ represents the battery resistance, and r and l represent the resistances of the connecting wires and an incandescent lamp, respectively.

For n lamps joined up in series, we must substitute nl for l, while if joined in multiple arc, we must put $\frac{l}{n}$ for l. In either case, the value of H is found to be a maximum, when the resistance of the lamp system is equal to that of the rest of the circuit.

Mr. Preece then proceeds on the assumption that this condition cannot be complied with, if n is large, reaching the conclusion that the amount of heat liberated in each lamp, varies inversely as the square of the number of lamps. This is true in either of the two cases discussed by him.

If, however, we have n lamps, arranged in n' parallel circuits, in each of which we have n'' lamps, the previous equation becomes

$$H''' = \frac{E^2 \frac{n''}{n'} l}{(\rho + r + \frac{n''}{n'} l)^2}$$

With this arrangement it is *always* possible to supply the condition which makes H''' a maximum, entirely irrespective of the value of n. If

$$\rho + r = \frac{n''}{n'} l$$

we shall have

$$H''' = \frac{E^2}{4(\rho + r)}$$

or the total heat in n lamps is independent of the number of lamps.

The heat generated in each lamp will then vary inversely as the number of lamps.

St. Louis, Dec. 30, 1879.

SCIENTIFIC INTELLIGENCE.

I. Physics and Chemistry.

1. *Why the air at the Equator is not hotter in January than in July;* by James Croll.—The following, I think, is the explanation of the difficulty why the January temperature at the equator when the earth is in perihelion is not much higher than in July when in aphelion. The difficulty is more apparent than real, for if we examine the *indirect* results which follow from the present distribution of land and water, we shall see that there is no reason whatever why the air at the equator should be hotter in January than in July.

It is well known that, notwithstanding the nearness of the sun in January, the influence of the present distribution of land and water is sufficient to make the mean temperature of the whole earth, or, what is the same, the mean temperature of the air over the surface of the earth higher in July than in January. The reason of this is obvious. Nearly all the land is in the northern hemisphere, while the southern hemisphere is for the most part water. The surface of the northern or land-hemisphere, for reasons to which I need not here refer, becomes heated in summer and cooled in winter to a far greater extent than the surface of the southern or water hemisphere. Consequently when we add the July or midsummer temperature of the northern to the July temperature of the southern hemisphere, we must get a higher number than when we add the January or midwinter temperature of the former to the January temperature of the latter. For example, the mean July temperature of the northern hemisphere, according to Dove ("Distribution of Heat on the Surface of the Globe") is 70°·9, and that of the southern hemisphere 53°·6; add the two together and we have 124°·5, which gives a mean for both hemispheres of 62°·3. The mean January temperature of the northern hemisphere is 48°·9, which, added to 59°·5, the mean January temperature of the southern hemisphere, gives only 108°·4, or a mean of 54°·2. Consequently the air over the surface of the globe is hotter in July by 8° than in January, notwithstanding the effects of eccentricity. It is obvious that, were it not for the counteracting effects of eccentricity, the difference would be much greater. Ten thousand years ago, when eccentricity and the distribution of land and water combined to produce the same effect, the difference must have been far greater than 8°.

But it will be asked, How can this affect the air over the equator, which is not situated more on the one hemisphere than on the other? It is true that those causes have but little *direct* effect on the air at the equator, but *indirectly* they have a very powerful influence. The air is continually flowing in to the equatorial regions from both hemispheres. In fact, the air which we find

there is derived entirely from the temperate regions. In July we have the northern trades coming from a hemisphere with a mean temperature as high as 70°·9, and the southern trades coming from a hemisphere with a mean temperature not under 53°, while in January the former trades flow from a hemisphere as low as 50°, and the latter from a hemisphere no higher than 60°. Consequently the air which the equatorial regions received from the trades must have a higher temperature in July than in January. The northern is the dominant hemisphere; it pours in hot air in July and cold air in January, and this effect is not counterbalanced by the air of the opposite hemisphere. The mean temperature of the air passing into the equatorial regions ought therefore to be much higher in July than in January, and this it no doubt would be were it not, let it be observed, for the counteracting effects of eccentricity. The tendency of the present distribution of land and water, when our northern winter occurs in perihelion, is to counteract the effects of eccentricity. But ten thousand years ago, when our winters were in aphelion, that cause would coöperate to intensify the effects of eccentricity. In fact, it would actually more than double the effects then produced by eccentricity. Now if the influence of the present distribution of land and water is so great as not merely to counteract but to reverse the effects of eccentricity to the extent of making the mean temperature of the earth 8° warmer in July than in January, it is not surprising that it should be sufficient to make the equatorial regions at least as warm in the former as in the latter period.

The fact that the equator at present is not hotter when the earth is in perihelion, instead of being an objection to the theory that the glacial period was due to an increase of eccentricity, as some suppose, is in reality another strong argument in its favor, for it shows that a much less amount of eccentricity would suffice to induce a commencement of glacial conditions in the northern hemisphere than would otherwise be required, were it not for the circumstance referred to.

There is another cause which must also tend to lower the January and raise the July temperature of the equator, viz: the northern trades pass further south in January than in July, and consequently cool the equatorial regions more during the former than the latter season. The general tendency of the trades to lower the temperature of the equatorial regions more in January than in July is of course subject to modifications from the monsoons, the rainy seasons, and other local causes; nevertheless, so long as the present distribution of land and water endures, so long will eccentricity have a counteracting effect upon the temperature of the air at the equator, which but for that would be hotter in July than in January.

No knowledge whatever as to the intensity of the sun's heat can be obtained from observations on the temperature of the air at the equator. The comparatively cold air flowing in from the temperate regions has not time to be fully heated by the sun's

rays before it rises as an ascending current and returns to the temperate regions from whence it came. More than this these trades prevent us from being able to determine with accuracy the intensity of the sun's heat from the temperature of the ground; for the surface of the ground in equatorial regions is kept at a much lower temperature by the air blowing over it than is due to the intensity of the sun's heat. It thus becomes a very intricate problem to determine how much the surface of the ground is kept below the maximum temperature by the heat absorbed by the moving air.—*Nature*, Dec. 11, 1879.

2. *Temperature of the Sun.*—Professor F. Rosetti, of the University of Padua, concludes a series of papers entitled—"Experimental researches on the temperature of the Sun," with the following remarks:—

The effective temperature of the sun may be defined as that temperature which an incandescent body of the same size placed at the same distance ought to have in order to produce the same thermal effect y if it had the maximum emissive power, i. e., E=1. In this place we could apply the formula

$$y = m\mathrm{T}^3(\mathrm{T}-\theta) - n(\mathrm{T}-\theta);$$

and if we consider the surrounding temperature during the observations to have been about 24°, giving $\theta = 297$, we obtain

$$\mathrm{T} = 10238°{\cdot}4;$$

so that the effective temperature of the sun, represented in degrees Centigrade, is

$$t = 9965°{\cdot}4,$$

if we only take into consideration the absorption produced by the terrestrial atmosphere. If we neglected this absorption we should have a lower temperature. In short, in the observations made, the maximum was obtained on September 28th at midday: this is represented by 210 scale-divisions, which gives y the value

$$y = 5{\cdot}6921 \times 210 = 1195{\cdot}3.$$

If we introduce this value into the formula, we obtain

$$\mathrm{T} = 8883{\cdot}8,$$

giving

$$t = 8610{\cdot}8.$$

This result will be greatly modified if we take into account the absorption exercised by the solar atmosphere. According to Secchi, the solar atmosphere exercises a very powerful absorption on the rays which proceed from the photosphere: on account of this absorption only $\frac{12}{100}$ of the solar radiation pass beyond the atmosphere of the sun, while $\frac{88}{100}$ are absorbed by it. If we regard this value given by Secchi as correct, we can calculate the thermal effect which the sun would produce if it were without atmosphere. This effect would be

$$y = 1838{\cdot}5 \times \frac{100}{12} = 15320{\cdot}8.$$

The formula gives

$$T = 20653{\cdot}7,$$

and consequently

$$t = 20380{\cdot}7.$$

There are still two causes which can modify these results; but certainly their effect is slight, since their influences are contrary and so compensate one another. One of these causes is the value of the specific emissive power of the sun, which may possibly be less than unity; and in that case the true temperature of the sun would be higher. The other cause is the transparency of the different strata of the solar atmosphere: although this is small, it is nevertheless certain that we receive the rays from several superposed strata; and although their temperature is certainly lower than that of the photosphere situated underneath, nevertheless to the radiation of the latter a portion of the radiation of these strata joins itself; and consequently in that case a lower temperature of the sun is sufficient to produce the heating measured by our instruments.

I think, then, that I may fairly conclude that the true temperature of the sun is not very different from its effective temperature, and that it is not much less than *ten thousand degrees* if we only consider the absorption of the terrestrial atmosphere, nor much more than *twenty thousand degrees* if we also take into consideration the absorption by the solar atmosphere, estimating the latter at $\frac{88}{100}$ of the total radiation of the sun.—*Phil. Mag.*, Supplementary No., 1879.

3. *The Pseudophone.*—For investigating the laws of Binaural Audition,* Professor S. P. Thompson has devised a little instrument which he calls the *pseudophone*, and which, as he states, is the analogue of the pseudoscope of Wheatstone, since it illustrates the laws of audition by means of the illusions it produces in the acoustic perception of space. It consists of a pair of ear-pieces furnished with adjustable metallic flaps or reflectors of sound, which can be fitted to the ears by straps and can be set at any desired angle with respect to the axis of the ears, and can also be turned upon a revolving collar about that axis so as to reflect sounds into the ears from any desired direction. In regard to its use the author says:

The estimate we are able to make of the position of a source of sound, judging solely by the relative intensities of the sensation in the two ears, depends upon our previous perceptions and upon our possession of a constant amount of effective auditory surface, and a constant angle subtended between the ears and the line of vision.

In the pseudophone these angles are variable, and the amount of effective surface can also be varied, and this without any knowledge, on the part of the person experimenting with the instrument, as to how much they may be varied. Hence the acoustic illusions which are now to be described.

* See this Journal, vol. xvii, 64, 322.

Suppose one flap to be adjusted at any angle of about forty degrees with the line of sight, in which position it is about most favorably situated to receive sounds from a point right in front of the observer; then if the other flap be adjusted to any angle greater or less than forty degrees, fewer rays of sound are reflected into the ear on that side than on the other, and the hearer imagines the source of sound to be situated on that side on which the sensation is more intense. Accordingly, to verify the perception, the hearer turns his head until both ears hear the sound equally loudly, and imagines then that he is looking in the direction of the sound, whereas he is looking at a point situated nearer to that side on which the larger effective surface exists. This observation agrees with Steinhauser's theory. The illusion is very easily obtained by means of a loud-ticking clock, but with some persons does not succeed unless their eyes are blindfolded; for when there is a conflict between the evidence of the eyes and the evidence of the ears, the tendency appears to be to believe the former rather than the latter.

A more striking illusion occurs when the flaps of the pseudophone are reversed and adjusted so as to reflect into the ears sounds which come from immediately behind the observer. In this case also, if a source of sound, situated anywhere behind the head, be observed, if the observer does not know how the flaps are adjusted, he will estimate it to be somewhere in front; and, on turning his head about until the sounds are equally intense, he judges himself to be looking straight at the source of sound, whereas it is in reality exactly in an opposite direction. This illusion succeeds well with a loud-ticking clock, well also with the human voice, but not well with a tuning-fork of medium pitch. In a room the experiment may succeed with a tuning-fork; but there is never the same clear and decisive impression as to the position of the sounding body. In the open air the writer has never succeeded in producing the illusion with a tuning-fork; for the sensation is one of a character from which it appears to be impossible to draw any precise judgment. The sound does not appear to *have* any precise locality. * * *

The illusion succeeds in the open as well as in-doors with the sound of a loud-ticking clock, and with the human voice; but with shrill sounds it succeeds best, notably with the sharp click of a metronome, and even with a metronome-bell.

Another experiment with the pseudophone, which gives rise to acoustical illusions, consists in setting one flap to catch sounds from the front, while the other catches sounds from behind or above the observer. Under these circumstances the sounds seem, as the observer moves his head, to come sometimes from the right, sometimes from the left, or sometimes from the ground.

Lastly, most of these experiments with the pseudophone can be repeated simply by holding the hands in front of the ears as flaps; but here the illusion does not always succeed, as the observer is conscious that his hands are reflecting to the ear sounds from a

certain direction, and so the judgment is sophisticated.—*Phil. Mag.*, November, 1879.

4. *Explosion of Carbonic Acid in a coal mine.*—M. DELESSE has given in the Comptes Rendus a short statement in regard to an explosion in the coal mine of Rochebelle (Gard), which caused the death of three miners. This explosion is explained as having been produced, not by fire-damp, for the detonation was not accompanied by flame nor was there any trace of burning found afterward, but by carbonic acid. It is suggested that the production of the gas was probably due to the action of a neighboring deposit of iron pyrites. This pyrite is strongly oxidized and in a complete state of decomposition; this would give a continual source of sulphuric acid, which, dissolving little by little in the subterranean waters, would meet the limestone below. In consequence a large amount of carbonic acid would be disengaged, penetrating the fissured beds of coal and finally, as the author argues, accumulating under so great a pressure as to lead to an explosion.

5. *On the Heat of Formation of Cyanogen.*—Since cyanogen is the only electro-negative compound radical thus far isolated, BERTHELOT has thought it desirable to determine the heat of its formation. For this purpose he burned it by means of oxygen, and found for the heat of its combustion CN=26 grams =+132·3 calories. Now the heat of combustion of the 12 grams of carbon it contains, referred to the condition of the diamond, is 94 calories. The difference is 38·3 calories, which is precisely the heat absorbed in the formation of cyanogen from its elements, C (diamond) +N =CN (gas) absorbs −38·3 calories. This fact, that cyanogen is formed from its elements with absorption of heat, was announced in 1864, and is now confirmed. Like acetylene C_2H_2 and nitrogen dioxide N_2O_2, cyanogen absorbs heat in its synthesis. This, Berthelot thinks, may be the reason why this body manifests in combining an energy comparable to that of the elements.—*Bull. Soc. Ch.*, II, xxxii, 385, Nov., 1879. G. F. B.

6. *First Book in Qualitative Chemistry*, by ALFRED B. PRESCOTT. 160 pp. 8vo New York, 1879. (D. Van Nostrand).—This little work has a character of its own in that it is designed not only to teach the ordinary simple method of analysis, but also to give the student at the same time a wider knowledge of chemical relations, and chemical facts, than he is likely to gain if his attention is directed exclusively to the differences upon which analytical methods are based. In the hands of a good teacher this book should give excellent results.

7. *Notes on Assaying and Assay Schemes;* by P. DE PEYSTER RICKETTS, E.M., Ph.D. Second edition, revised and enlarged. 210 pp. 8vo. New York, 1879. (J. Wiley & Son.)—We noticed this useful volume on its first appearance. The second edition contains important additions and corrections. Dr. Chandler's happy conception of the Assay Ton (A. T.), by which the ton of 2000 lbs. stands to the A. T. as one ounce Troy to one milligram, is now in general use in the United States, and is of course

used in these "Notes." Dr. Ricketts is at the head of the assay laboratory of the Columbia College School of Mines, and these "Notes" are the daily guide of the students of that institution. It is a particularly practical book and well adapted to its objects.

8. *Chemical Problems*, by JAMES C. FOYE. 43 pp. 8vo. Appleton's Misc., 1879.—Many teachers may find their work facilitated by having a series of problems on the fundamental principles of chemistry prepared for them.

II. GEOLOGY AND MINERALOGY.

1. *A Manual of the Geology of India.* Chiefly compiled from the Observations of the Geological Survey by H. B. MEDLICOTT, M.A., Superintendent Geological Survey of India, and W. T. BLANFORD, F.R.S., Deputy Superintendent. 2 vols. roy. 8vo, in all 820 pp., with a map, and 21 lithogr. plates.—The authors of this Manual of India Geology are prominent members of the corps connected with the Government Geological Survey; and the work may therefore be received as a faithful presentation of the latest results obtained. The facts and views are ably set forth, and those relating to fossils are well illustrated in the many plates. The work has a high interest to geologists of the other hemisphere, because of the striking contrasts with the geology of Europe and North America which it affords, while sustaining the same general truths and principles.

The work is divided into Part I (occupying volume i), treating of the Peninsular area of India, and Part II (volume ii), of the Extra-peninsular area; and both the physical geography and geology of these areas are treated of.

The following are some of the peculiarities in the geology of India which are described at length in the volumes.

(1.) The division into Peninsular and Extra-peninsular India by the broad plain of the Indus and Ganges, at the foot of the interior mountain region; "the Extra-peninsular area is geologically an intrinsic portion of the Asiatic continent, whilst Peninsular India is not."

(2.) The absence of *marine* fossiliferous beds older than Tertiary in Peninsular India, excepting some Jurassic and Cretaceous in the Cutch and Jessalmir just northwest, and similar beds along the east coast, although there are unaltered sedimentary rocks of great thickness from the Cretaceous to the Lower Silurian (?), with metamorphic rocks underneath; first, a great "Vindhyan" formation, north of the Narbada, 12,000 feet thick, consisting of limestones and shales in many alternations; and, secondly, the Gondwana, or plant-bearing and coal-bearing series, of wide extent, the lower portion of which (the Talchir and Damuda groups), are referred to the Permian and Triassic, and the upper (the Mahadeva and Rajmahal) to the Jurassic.*

* The only animal fossils of the Damuda series are an Estheria, some Labyrinthodont and true Reptiles (a Dicynodon (also a Karoo form), and the Dinosaur, *Ancestrodon Indicus*).

The occurrence of marine fossiliferous beds of Silurian, Devonian, Carboniferous, Triassic, Jurassic, Cretaceous and Tertiary age in the mountain regions of the Extra-peninsular area.

(3.) The Coal-period of the country having its commencement in the Permian and reaching its maximum in the Triassic (the period of the Damuda group): showing that the era of gentle oscillations about such a mean plane of level as would make wide-spread marshes in alternation with wide-spread shallow waters, came later than in the hemisphere of Europe and America, and that these diverse hemispheres did not correspond in limit with the north and south hemispheres of the sphere.

(4.) A close relation in species between the Coal-plants (species of *Glossopteris*, etc.), of the Talchir and Damuda groups and those of the Coal-fields of Eastern Australia, and also those of Southern Africa (the Karoo beds), showing that these three distant portions of the globe had certain common relations in that era.

(5.) A close relation between the Reptilian and Amphibian fauna of the Later Gondwana beds and that of the upper beds of the Karoo series.*

(6.) The existence, in the Talchir group, among finer strata, especially toward the base of the group, of beds of bowlders, the bowlders rounded, from half an inch in diameter to fifteen feet and thirty tons in weight, some of them with scratched and smoothed surfaces; and of similar bowlder beds in the lower of the South Africa deposits in the Karoo region.

(7.) The existence in the Lower Vindhyan series, in Southern India, of a diamond-bearing conglomerate or grit, ten to twenty feet thick (of dark gray, red and brown colors), which is explored for diamonds by means of shallow pits and short galleries—the diamonds supposed to be probably "of detrital origin," like the pebbles and other material of the enclosing rock; also of another similar diamond-bearing conglomerate in the Upper Vindhyans, on the borders of the Bundelkand gneiss; besides alluvial diggings.

(8.) In Extra-peninsular India, the occurrence of Eocene Nummulitic strata, with underlying Cretaceous and usually overlying beds of later Tertiary, at a height of 7,000 feet, on the tops of the hills of Khirthar, in Western Sind, and still higher, in the Pun-

The upper part of the Gondwana, in the Rajmahal hills and elsewhere, contains numerous species of Cycads as well as Ferns and Conifers, which indicate a Jurassic age, and a relation also to the flora of beds overlying the Karoo series of South Africa. A number of fossil fishes, and some Reptile remains occur in the beds, and near Ellore and Ongole. and near Madras, in the upper beds, there are Ammonites and other Mollusks, having Jurassic affinities. In Cutch and to the northwest are other Jurassic rocks, about 6,000 feet thick, containing numerous marine fossils, and it is the only case of the kind in the Peninsula of India. The fossils are species of *Trigonia*, *Gervillia*, *Pholadomya*, *Lima*, *Exogyra*, *Belemnites*, various *Ammonites*, etc. *Trigonia ventricosa* occurs also in the uppermost Jurassic rocks of South Africa, as well as in the upper beds of the Gondwana series, near Rájámahendri. Marine Cretaceous beds with fossils occur in Cutch, in Pondicherry and Trichonopoly in Southern India, and between Mandlesir and Broach in the Narbada valley. The marine Tertiary beds of the Peninsular area are confined to a narrow fringe along or near the coast.

jab, to the north, along the Suleman Range to Peshawar; in the "Salt Range;" in Northern Punjab, through the Hazára and the Murree Hills, and other hills west of the Indus; and along a region 200 miles or more long and 25 wide in Tibet, in the upper Indus valley, 15,000 feet above the sea level.* (The statement, by Dr. Thomson, as to the occurrence of Nummulitic beds on the Singhi Pass, at a height of 16,600 feet, is said to need confirmation, because of the importance of the fact, if true.)

(9.) A thickness of Tertiary in the Sub-Himalayas (a range of mountain ridges, fifty miles in width, 5,000 to 8,000 and rarely 12,000 feet high) of 12,000 to 15,000 feet, with the beds much folded, but conformably with the underlying beds; in the Punjab, of 25,000 feet thick, 15,000 feet being of the Siwalik formation or Upper Tertiary; in Sind, in the Mountains of Khirthar, 8,000 to 10,000 feet for the Pliocene (Manchhar group) alone, the beds much folded, (related to the Pliocene of the Siwalik Hills).

(10.) In the Punjab, beyond the parallel of 32°, between the Indus and Jhelun, the "Salt Range," including strata ranging from the Silurian (?) to the Pliocene, many containing marine fossils, the Sub-Carboniferous limestone being well displayed and extending into Kashmir.

(11.) Salt-bearing beds (Silurian?) at the base of the series of the "Salt Range," the salt layers often 100 feet thick, and at the Mayo Mines of Khewa, containing 550 feet of pure and impure salt, in a thickness of 1,000 feet; also, in the Kohát region, in the Punjab, underneath Nummulitic beds, beds of rock salt and gypsum of great thickness, exceeding 1,000 feet near Bahádur Khel, with a width of outcrop of a quarter of a mile, and ridges of rock salt 200 feet high standing in the region.

(12.) Trap rocks, doleryte and basalt—the "Deccan trap"—of great geographical extent, reaching, with even horizontality, from the sea-coast at Bombay (72° 51′ E.) to the head of the Narbada (82° E.), and from near Belgaum (15° 35′ N.) to north of Goona (25° N.), an area, covering about 16 degrees of longitude and 9½ of latitude, little less than 200,000 square miles (the railway from Bombay to Nágpur, 519 miles long, never leaving the volcanic rocks until it is close to the Nágpur station); and all subaerial in origin; probably erupted at or near the close of the Cretaceous or during the Lower Tertiary, in successive outflows occurring at intervals during a long period; the thickness near Bombay, 6,000 feet; in Cutch, about 2,500; in Sind, only 200 in two bands; in Belgaum, at the southern limit, 2,000 to 2,500 feet; to the southeast, near Rájámahendri, 100 to 200 feet.

* The Indus in the Central Himalayas flows in a direction about N. 50° W., between the Zanskar gneiss range on the south and that of Ladak on the north; and these Eocene beds extend, according to Stoliczka, from Kargil, on the west, eastward for more than 200 miles, to beyond the eastern limit of his explorations. The Zanskar contains also 8,000 to 9,000 feet of fossiliferous Cretaceous, Jurassic, Triassic, Carboniferous and Silurian beds, all conformable. The Zanskar range contains several peaks 20,000 feet in height, and "has a right to be considered the principal continuation of the Himalayan chain." Its gneiss is "to some extent, at least, a rock formed of converted Paleozoic strata."

(13.) Other extensive trappean outflows in the Rajmahal region, west of the delta of the Ganges, 2,000 feet thick, probably from Jurassic to Upper Cretaceous in age, but supposed by some to have been cotemporaneous with the Deccan outflows, with "little petrological distinction between the traps" of the two regions; and still others in the Sylhet region, east of the delta, overlaid by Cretaceous rocks.

(14.) A line of eruptive rocks on the Upper Indus, from Kargil eastward, accompanying the Eocene strata "from end to end."

The above indicate some of the points which the reader will find presented in full in the volumes.

With regard to the movements producing the Himalayas, the work makes the following remarks in the brief geological summary with which the work commences (pages lvi, lvii).

We cite, in closing this notice, the following general remarks (from pages lvi, lvii) on the *Origin of the Himalayas.*—During the interval that has elapsed since Eocene times, whilst no important movements, except small and partial changes of elevation, can be traced in the Peninsula, the whole of the gigantic forces, to which the contortion and folding of the Himalayas and other Extra-peninsular mountains are due, must have been exercised. The Sub-Himalayan Eocene beds were deposited upon uncontorted Paleozoic rocks; and although the Himalayan area was probably in great part land at a much earlier period, there is no reason for believing that this land was of unusual elevation, whilst the direction of the Himalayan ranges is clearly due to post-Eocene disturbance. It will be shewn, in the chapters relating to the Sub-Himalayan rocks, that the movement has been distributed over the Tertiary and post-Tertiary period; and a great portion is of post-Pliocene date. Indeed, the fact that earthquakes are now of common occurrence in the Himalayas, the Assam hills, Burma, Cutch, and Sind, and that many of the shocks are severe and some violent, whilst the Peninsular area is but rarely affected by earthquakes, may indicate that the forces, to which the elevation and contortion of the Himalayas are due, are still in action; and that the highest mountains in this world owe their height to the fact that the process of elevation is still in progress, to a sufficient extent to counterbalance the effects of denudation.

In Sind and the Sulemán ranges, there is much probability that some movement took place during Miocene and Pliocene times. Some slight unconformity between beds, elsewhere conformable, and the absence of different groups in parts of the country, may thus be explained; but the principal disturbance is clearly of post-Pliocene date. To the eastward, in Burma, however, the Pliocene formations of the Irawadi valley are but little disturbed, and the Miocene beds, although contorted, are unaltered; whilst many of the Eocene and Cretaceous rocks are greatly changed, besides having undergone excessive disturbance and folding. These facts may, perhaps, indicate that the disturb-

ing forces were more severe to the eastward in middle Tertiary times, and that the main action to the westward was of later date: a view partly supported by the fact that there is evidence of elevation having taken place in the Himalayas near the Ganges and Sutlej, at an earlier period than farther to the westward. In the Simla area, there is marked unconformity, due evidently to upheaval and denudation combined, between the Sirmúr and Siwalik series, and between the lower, or Náhan, group of the Siwalik series itself and the next overlying sub-division; whereas farther west, in the Northern Punjab, all the groups follow each other in apparently conformable sequence. The evidence, however, is not sufficient to prove that the contortion to the eastward is older than to the westward; and the absence of any important break in Burma is opposed to the suggestion of great movements having taken place in that country in early or middle Tertiary times.

It is evident that the forces, to which the principal ranges in the Extra-peninsular area owe their direction, have not only been exerted throughout a considerable portion of the Tertiary period, but that these forces have acted contemporaneously, at all events in the post-Pliocene period."

2. *Note on the Trilobite, Atops trilineatus of Emmons;* by S. W. Ford.—In his paper on "*Fossils of the Utica Slate and Metamorphoses of Triarthrus Beckii*," noticed on page 152 of this Journal for August, 1879, Mr. C. D. Walcott includes in his list of synonyms of *Triarthrus Beckii*, *Atops trilineatus* Emmons, 1844, Taconic System, p. 20; and *Atops trilineatus* Emm., 1846, Agr. Rep. N. Y., vol. i, p. 64. The figures are the same in the two publications cited. The species represented by Emmons is not the *Triarthrus Beckii*, and of the Utica Slate, nor is it that species and of the Hudson River group, as maintained by Hall, but has since been shown to belong to the genus *Conocoryphe* and to characterize the Primordial. It has not yet been met with beyond the State of New York, nor at any point west of the Hudson River. In an earlier part of his paper, Mr. Walcott treats of the views entertained by Mather concerning the rocks upon the east side of the Hudson, quoting from that geologist to prove that he considered them to represent all the members of the Champlain division, and these only; and he then proceeds to speak of "Mr. Dale's discovery of an old locality given by Mather," and the writer's "verification of the presence of a lower member of the Champlain division by paleontological evidence," as serving simply to confirm Mather's views.

Whatever may be thought of Mr. Dale's discoveries, I am satisfied that their intrinsic value will not be at all lessened by Mr. Walcott's method of putting things. The important fact still remains, that, up to the date of Mr. Dale's discovery of Hudson River fossils at Poughkeepsie, the age of the slates occurring there was unknown. With regard to myself I may say that I am far from regarding the Primordial beds of Troy, N. Y., as representing any portion of the Champlain division as generally under-

stood, and have so expressed myself in former papers. The evidence respecting the horizon of these beds is mainly paleontological; and this, as it at present stands, shows that their fauna, though closely linked generically with that of the Potsdam sandstone (or true base of the Champlain division) on the one hand, and the Acadian on the other, yet has a decided *leaning* in this respect toward that of the Acadian. Specifically it is entirely distinct from both. Until, therefore, more is known upon the subject, it seems to me an obvious over-reaching of facts to refer the beds in question unqualifiedly to the Champlain division of the New York System.

New York, December 12th, 1879.

3. *List of Papers on the Taconic System;* by JAMES D. DANA. —As an Appendix to my last paper on the Taconic System, published in vol. xvii of this Journal (May, 1879, p. 375), I have prepared a list of the principal papers on the subject. It contains those treating of the true original Taconic, and of the changes in the limits of the Taconic system which Emmons introduced; but the papers which bear only on the age of accessories to the system are not included, since they never had any right to a place in the system and their age has no bearing on the question as to the age of the true Taconic. The list is in two parts; first, that of papers sustaining the pre-Silurian (pre-Potsdam) age of the Taconic system; and secondly, that of papers adverse to this view of their age.

I. IN FAVOR OF ITS INFERIOR POSITION AND UNCONFORMABILITY TO THE NEW YORK SILURIAN.

EBENEZER EMMONS: Rep. Geol. New York, 4to, 1842, pp. 113–164; announces the Taconic system as Lower Cambrian, and includes in it, besides the schists o the Taconic Mountains (in the vicinity of which, at Williamstown, Professor Emmons for a while lived) and other slates to the north, and west to the Hudson, also the associated crystalline and semicrystalline limestones and quartzyte.—IDEM: Rep. Agric., New York, Part v, 4to, 1846, pp. 45–112; describes the system with more detail, and extends it to include rocks in Maine, Rhode Island and Michigan.—IDEM: American Geologist, 8vo, volume i, 1855, Part ii, pp. 1–124; extends the system from Maine to Georgia, divides it into Upper and Lower, the slates, limestones, and magnesian slates of the original Taconic, with their supposed equivalents, being made the Lower, and some added fossiliferous rocks [Primordial and later], with their supposed equivalents, the Upper.—IDEM: Report on the North Carolina Geol. Survey, 8vo, 1856, pp. 49–72.

E. & C. H. HITCHCOCK: Report on the Geology of Vermont, 2 vols., 4to, 1861; sustains the system, but half strangles it by the paleontological facts it reports.—F. MARCOU, Comptes Rendus, Nov. 4, 1861, and Proc. Boston Soc. Nat. Hist., 1862; adds the Potsdam sandstone and the gneiss of the Green Mountains to the Taconic system.

T. S. HUNT: Proc. Boston Soc. Nat. Hist., xix, 275, 1878; refers the "Upper Taconic," "wholly uncrystalline," to "the Quebec Group of Logan;" but the "Lower Taconic," here called *Taconian* (and made to include the crystalline schist of the Taconic Mountains, "along the outcrop" of which occur "the great masses of brown hematite ore" [or limonite], associated with magnesian limestones, from Vermont to Alabama), to the lowest Cambrian, or a still lower formation. containing *Scolithus* and *Eozoon*.—IDEM: Pennsylvania Geol. Report, on Azoic Rocks, Part i, 1878; uses the name *Taconian* (p. 207), with the same definition, but makes the Upper Taconic to include the Quebec Group and (pp. 115, 116, 206) organic remains of the European Cambrian at least as low as the Menevian."

II. IN FAVOR OF THE IDENTITY OF THE TACONIC SYSTEM WITH PART OR ALL OF THE NEW YORK LOWER SILURIAN. (The Lower Silurian is called *Champlain Division* by Mather).

H. D. & W. B. ROGERS: Proc Amer. Phil. Soc., Jan. 1, 1841; make the slates of the Taconic Mountains and the rocks east and west to be Lower Silurian, and refer the slates to the Hudson River group.—W. W. MATHER: Report Geol. N. York, 4to., 1843; gives many sections and announces the same conclusions, arguing against the Taconic system.—H. D. ROGERS: Address, etc., Rep. Amer. Assoc. Geol. & Nat., for 1844, p. 67, and Amer. J. Sci., xlvii, 137, 1844; urges the same views essentially.—JAMES HALL: ibid., p. 68.

T. S. HUNT, "of the Geological Commission of Canada:" On the Taconic System, Report Amer. Assoc., for 1850 (New Haven meeting) says, "The results of the [Canada] survey have shown, as I had the honor to state at the last annual meeting at Cambridge [in 1849], that the Green Mountain rocks are nothing else than the rocks of the Hudson River group with the Shawangunk conglomerates, in a metamorphic condition."—JAMES HALL: N. Y. Palæontology, vol. iii, p. 15, 1859.—T. S. HUNT: Amer. J. Sci., II, xxxi, 402, 1861 (after Logan's defining of the Quebec group); says, "the Quebec group with its underlying shales is no other than the Taconic system of Emmons."—IDEM: ibid., xxxii, 427, 1861; makes the Taconic, exclusive of the slates, equivalent of the Calciferous, adding that "it remains to be seen whether Dr. Emmons can retain from the wreck of his system, the lower slates as a Tacanic formation older than the Potsdam."—W. E. LOGAN: Geology of Canada, 8vo, 1863, p. 934; makes the system to consist, "for the greater part at least, of the strata of the Potsdam and Quebec Group."—J. D. DANA: Manual of Geology, 1863; cites and adopts the views just mentioned.—JAMES HALL and W. E. LOGAN: Amer. J. Sci., II, xxxix, 96, 1865; refer the Hudson River slates south of Albany to the Quebec group.—T. S. HUNT: Address, etc., Rep. Amer. Assoc., for 1871; refers the Stockbridge or Green Mountain limestone to the Quebec group, and states that the conclusion of Rogers and Mather referring the Taconic system to the "Champlain Division" of the New York rocks had been sustained by subsequent observations (pp. 15 and 23).

J. D. DANA: On the Rocks of the vicinity of Great Barrington, Mass., Amer. J. Sci., III, iv, vi, 1872, 1873; gives sections showing the *conformability* of the Taconic slates, "magnesia schists" (slates and schists making the Taconic Mountains), Stockbridge limestone, and quartzyte (the original Taconic rocks of Emmons), and makes the limestone (on the basis of Billings's report of Wing's discoveries), Trenton and Chazy, and the Taconic schists and slates of Hudson River age.—A. WING: Discoveries in Vermont, ibid., xiii, 1877; shows, *by their fossils*, that the "Stockbridge limestone" and "Sparry limestone" of the Taconic System of Emmons in Vermont, are Lower Silurian, from Potsdam to Trenton, inclusive, and that the Taconic slates *overlie* the limestones.—J. D. DANA: On the Relations of the Geology of Vermont to that of Berkshire, ibid., xiv, 1877; gives new sections proving the conformablity before announced, and sustains the conclusion that the Taconic schists and slates (those of the Taconic Mountains) are of Hudson River age, and the limestones Lower Silurian, and shows also that mica schist, gneiss and other crystalline rocks are included among the *conformable* Lower Silurian strata.—FREDERICK PRIME, JR.: Lower Silurian Fossils in limestone associated with Hydromica Slates in Eastern Pennsylvania, ibid., xv, 261, 1878; shows the Chazy or Trenton age of the rocks, which are part of the so-called Taconic, and are like those of Berkshire.—T. NELSON DALE: Discovery of fossils, *proving the Hudson River age* of the supposed Taconic Poughkeepsie slates.—J. D. DANA: On the Hudson River Age of the Taconic schists, ibid., xvii, 375, 1879; announces the discovery of Trenton fossils in the Barnegat or Wappinger Valley limestone (which adjoins the Poughkeepsie slates), and proves the conformability of the Poughkeepsie slates with the slates of the Taconic Mountains, as exhibited in Mather's sections and the continuity and conformability of the Dutchess County slates and limestones with those of the Taconic System of Massachusetts and Vermont.—W. B. DWIGHT: Fossils of the Wappinger Valley Limestone, ibid., 389; adds to the number of localities, and gives lists of Trenton fossils, 50. —WHITFIELD: On the occurrence of Maclurea of the Chazy beds in the Barnegat Limestone near Newburgh, New York, ibid., xviii, 227, 1879.—W. B. DWIGHT: On Calciferous as well as Trenton fossils in the Barnegat lime-

stone at Rochdale and in Trenton in the same near Newburgh, N. Y., ibid., xix, 71, 1880.—J. P. LESLEY: On the discovery by P. Frazer, of Hudson River or Trenton *Buthotrephis* in slates on the Susquehanna, near the borders of Pennsylvania and Maryland, ibid., xix, 71, 1880.—Proc. Amer. Phil. Soc., xviii, 365.

4. *The Cave Bear of California;* by E. D. COPE.—In exploring a cavern in the Carboniferous limestone of Shasta county, Cal., James D. Richardson discovered the skull of a bear beneath several inches of cave earth and stalagmite. The specimen is in a good state of preservation, and demonstrates that the cave bear of that region was a species distinct alike from the cave bear of the East (*Ursus pristinus*), and from any of the existing species. In dimensions the skull equals that of the grizzly bear, but it is very differently proportioned. The muzzle is much shorter, and is wide, and descends obliquely downward from the very convex frontal region. It wants the large postorbital processes of the grizzly, but has the tuberosities of the polar bear (*U. maritimus*), which it also resembles in the convexity of the front. Sagittal crest well developed. Three (one median and posterior) incisive foramina: three external infraorbital foramina. The teeth are large, and the series presents the peculiarity of being without diastema. The crowns of the premolars are not preserved, but if there were not three premolars, the second tooth has two well-developed roots. First true molar with but two external and one internal tubercle. The absence of diastema renders it necessary to separate this bear from the true *Ursi*, and I propose to regard it, provisionally, as a species of *Arctotherium* Gerv. The canine teeth are large and compressed at the base. Length of cranium along base from below apex of union to premaxillary border, 0·387^{m}; length to posterior nares, ·202; elevation of forehead vertically above the posterior extremity of the last molar, ·141; width between inner border of posterior molars, ·076. The species may be called *Arctotherium simum.*—*American Naturalist*, December, 1879.

5. *On the Miocene Fauna of Oregon;* by E. D. COPE.—This paper, published in the Proceedings of the American Philosophical Society, Dec. 5, 1879, is the third by Professor Cope on the Miocene Mammals of Oregon. The first appeared in the Proceedings of the same society for November, 1878, and the second in the Bulletin of the United States Geological Survey of the Territories for February, 1879. The latter article contains an enumeration of seven species of mammals, discovered in the Truckee beds of the White River formation of Oregon. Since the date of the latter paper Professor Cope has been engaged in exploring the region; "the expeditions being mostly under the direction of Jacob L. Wortman." This paper contains the descriptions of some of the new species obtained, namely: *Hesperomys nematodon*, *Sciurus Vortmani*, *Paciculus insolitus*, *Canis lemur*, *Amphicyon entoptychi*, *Archælurus debilis*, *Hoplophoneus platycopis*, *Chænohyus decedens*, *Thinohyus trichænus*, *Palæochœrus subæquans*, *Merycopater Guiotianus*, *Coloreodon ferox*, *Coloreodon macrocephalus.* Professor Cope states that Mr. Wortman, to whom he is indebted

for several of the above, has sent remains also of *Lacertilia* and *Ophidia*, orders previously unknown from the Miocene of Oregon, but made known by him as occurring in the White River formation of Colorado in 1873.

6. *Ueber die erzführenden Tieferuptionen von Zinnwald-Altenberg und über den Zinnbergbau in diesem Gebiete;* by EDWARD REYER. *Tektonik der Granitergüsse von Neudeck und Karlsbad und Geschichte des Zinnbergbaues im Erzgebirge;* by the same. *Banka und Bilitong;* by the same.—The earlier studies of Dr. Reyer, entitled, "die Euganeen: Bau und Geschichte eines Vulcanes," and "Beitrag zur Fysik der Eruptionen und der Eruptivgesteine," are already well known by those interested in the subjects of which they treat. The series of papers whose titles are given above are based in part upon the theories advanced in these former memoirs. They contain detailed descriptions of the method of occurrence of the tin ore in the Erzgebirge of Bohemia, speculations as to its genesis, and also many valuable and interesting facts in regard to the history of the tin-mining industry.

7. *Brachiopodes: Etudes Locales.* Extraits du Systême Silurien du centre de la Bohême; vol. v, Brachiopodes. I. Variations observées parmi Brachiopodes siluriens de la Bohême. II. Distribution verticale des genres et espèces de Brachiopodes dans le bassin silurien de la Bohême. III. Connexions spécifiques établies par les Brachiopodes entre les faunes siluriennes de la Bohême et les faunes paléozoïques des contrées étrangères; par JOACHIM BARRANDE. 356 pp. and 7 plates, 4to. Prague and Paris, 1879.

8. *Geological Survey of Japan.* Reports of Progress for 1878 and 1879; by BENJ. SMITH LYMAN. 266 pp. 8vo. Tookei, 1879.

9. *Lethæa Geognostica, oder Beschreibung und Abbildung der für die Gebirgs-Formationen bezeichnendsten Versteinerungen,* herausgegeben von einer Vereinigung von Paläontologen. I Theil, Lethæa palæozoica von FRED. ROEMER. 1ste Lieferung. 324 pp. 8vo. Stuttgart, 1880 (E. Schweizerbart'sche Verlagshandlung—E. Koch). An Atlas to this work was published in 1876; it contains sixty-two plates, illustrating the fossil plants and animals of the successive Paleozoic formations, from the Cambrian to the Permian inclusive.

10. *Neues Jahrbuch für Mineralogie, Geologie, Paleontologie.*—A new decade of the "Jahrbuch" begins with 1880, and with it it is announced several changes will be made which are calculated to increase its usefulness. There are to be in future six numbers yearly, in two volumes, which together will include one-half more matter than the annual volumes hitherto issued. Various other changes in the selection and arrangement of the matter (some of them of considerable importance), are also proposed. The editors, Professors Benecke, Klein and Rosenbusch are doing a great service to science in perfecting and making more complete the journal which has been intrusted to their care.

11. *Mineralogische Notizen von* A. VON LASAULX.—Professor Lasaulx describes a new mineral species under the name of *Tita-*

nomorphite. It occurs as an alteration product, forming a white coating about a nucleus consisting of rutile or menaccanite, or both. This coating has in part a radiated fibrous structure, but on the outside is granular. The grains in some instances admitted of a crystallographic and optical examination, which showed a close relation between the mineral and titanite. An analysis by Bettendorff afforded TiO_2 74·32, CaO 25·27, FeO tr=99·59, which corresponds to the formula $CaTi_2O_5$. Found in the amphibolyte of the "Hohe Eule," Silesia. It is regarded by Lasaulx as probably identical with the white decomposition product from menaccanite or rutile often observed in microscopic sections of rocks but hitherto of uncertain composition.

Professor Lasaulx also describes a manganese vesuvianite (3·23 p. c. MnO) from the neighborhood of Jordansmühl, in Silesia, and gismondite from the basalt of Schlauroth, near Görlitz. The crystals of gismondite are shown to be generally twins, belonging to the triclinic system.—*Zeitsch. Kryst.*, iv, 162.

12. *Mineralogische Notizen*, von V. von Zepharovich.—Professor Zepharovich describes interesting crystals of calcite and cerussite from Bleiberg, the former with the rhombohedron $R\frac{4}{5}$; also of sulphur, pyrite, and arsenical pyrites.

13. *Ueber die optische Orientirung der Plagioklase* von Max Schuster.—The results reached by DesCloizeaux in his optical examination of the triclinic feldspars were regarded by him as strong arguments against the correctness of the theory of Tschermak, that they are isomorphous mixtures of anorthite and albite in varying proportions, with these two species as the extremes. The subject has been farther investigated by Schuster, and as his result, he states:—that the lime-soda feldspars form in their optical relations a series analogous to that which connects them in their other characters; and further, each definite ratio in the mixture of the albite and anorthite corresponds to a definite optical relation approaching the one or the other of these two species. It is also shown that microcline and orthoclase are related to the other feldspar species in the position of the plane of the optic axes, and in the position of the positive bisectrix.—*Ber. Ak. Wien*, lxxx, July, 1879.

14. *Ueber den Perowskit von* H. Baumhauer.—The true crystalline form of the rare species perofskite has long been in question, and has been discussed by DesCloizeaux, Kokscharow, Hessenberg and others. Baumhauer has applied the method of etching to crystals from several localities, and has confirmed an opinion previously expressed by others, that they belong in fact to the orthorhombic system.

III. Botany and Zoology.

1. *The Botanical Gazette, a Paper of Botanical Notes*, edited by Prof. J. M. Coulter and M. S. Coulter, has completed its fourth year, and its existence is now assured. The principal editor is now a professor in Wabash University, at Crawfordsville, Indi-

ana, where the Gazette is now published, in monthly numbers, at the low price of a dollar per year. It is an organ for communication among botanists, for the prompt publication of notes and observations, and of those contributions to knowledge which every accurate observer may do his part in, but which must be collected in order to be preserved and utilized. New species are published or announced in it, but it is rather an organ for new observations and botanical news. It is well conducted; it is very useful; we learn that it is in a condition which ensures its continuance, and that every increase in the subscription will go toward increasing its value. Our botanists should now see that it is worthily supported. Indeed they can hardly do without it. A. G.

2. *Additions to the Botanical Necrology of* 1879.—Our obituary list was drawn up earlier than usual, so that it might appear in the January number of the Journal. Two additions are already to be made to it.

Ferdinand Lindheimer died, at New Braunfels, Texas, in the early part of December, at the age of about 78. The Texan newspaper which announces his decease states that he was a volunteer in the Texas revolution under Gen. Houston. He was for many years editor of a German newspaper published at New Braunfels. He was an assiduous and excellent collector and a keen observer; the notes upon his specimens are full and discriminating, and added not a little to the value of the collections which were distributed by his friend and correspondent, Dr. Engelmann, and to the publication, *Plantæ Lindheimerianæ*, in which a large part of them were published and annotated. Various new species discovered by him bear his name, which is also commemorated by a peculiar genus of *Compositæ*, discovered by him. *Lindheimera Texana* is a very pretty Texan annual, which has remained in cultivation for nearly forty years, at least in botanical gardens; and a Mexican species has recently been made known, from the collections of Dr. Parry and Dr. Palmer. Hardly any name is more identified with the botany of his adopted State than that of the worthy Lindheimer. A. G.

Charles Henry Godet, of Neufchatel, author of the Flora du Jura, died December 16, in the 83d year of his age. This venerable botanist and most estimable man was a very critical student of the European flora. He took a lively interest in that of our own country; so it is pleasant to remember that his name is borne by a peculiarly North American genus, containing over a dozen handsome annuals, mainly Californian, several of them prized ornaments of the flower garden. *Godetia* of Spach was reduced by Torrey and Gray and their contemporaries to a section of the genus (*Œnothera*) from which it was originally taken. But it has been restored by Sereno Watson, and it may be expected to hold its ground. It commemorates the services to science of a keen and sound botanist and a charming man. A. G.

3. *Das Microgonidium: ein Beitrag zur Kenntniss der wahren Wesens der Flechter:* von Dr. Arthur Minks, Mittgl. mehr.

gelehrter Gesellschaften. Mit 6 colorirten Tafeln. 249 pp. 8vo. Basel, Genf. Lyon, (St. George's Verlag). 1879.—This work, noticed already by the present writer in this Journal, has happily at length made its appearance in very handsome form, and commends itself to all, at least to cryptogamic botanists. It is impossible to question either the care or the sincerity of the author; and if any views on the topic of this memoir demand attention from those qualified to consider them, certainly his do. Further notice must be postponed. E. T.

4. *Bulletin of the United States Geological and Geographical Survey of the Territories;* F. V. HAYDEN, Geologist-in-charge. Vol. v, No. 3, 331–520 pp. Washington, 1879.—This number contains the following papers: on the species of the genus Bassaris, by J. A. ALLEN: the American Bembicidæ; Tribe Stizini, by W. H. PATTON; list of a collection of aculeate Hymenoptera made by S. W. Williston in northwestern Kansas, by W. H. PATTON; further notes on the Ornithology of the Lower Rio Grande of Texas from observations made in the Spring of 1878, by G. B. SENNETT, edited by Dr. ELLIOTT COUES; additional lists of elevations, by HENRY GANNETT; generic arrangement of bees allied to Melissodes and Anthophora, by W. H. PATTON; annotated list of the birds of Michigan, by Dr. MORRIS GIBBS; the Coleoptera of the Alpine Rocky Mountain Region, part II, by JOHN L. LECONTE, M.D.

5. *Mittheilungen aus der Zoologischen Station zu Neapel*, zugleich ein Repertorium für Mittelmeerkunde. Vol. i, in 4 numbers. 592 pp. 8vo, with 18 plates. Leipzig, 1879. Wilhelm Engelmann.)

6. *Bulletin of the Museum of Comparative Zoology at Harvard College, Cambridge.* Vol. v, number 16. On the Jaw and Lingual Dentition of certain terrestrial Mollusks, by W. G. BINNEY. 331–368 pp., with 2 plates. Cambridge, 1879.

7. *Paleozoic Cockroaches: A complete revision of the Species of both Worlds, with an essay toward their classification;* by SAMUEL H. SCUDDER. 134 pp. 4to, with 6 plates. Boston, 1879. (Memoirs of the Boston Society of Natural History, vol. iii, part I, number 3).

8. *Insects from the Tertiary Beds of the Nicola and Similkameen Rivers, British Columbia;* by S. H. SCUDDER. (Geol. Survey of Canada, 1877–78.)

IV. ASTRONOMY.

1. *On the Secular Changes in the elements of the orbit of a Satellite revolving about a planet distorted by Tides;** by G. H. DARWIN.—The investigation which forms the subject of this paper is entirely mathematical, and is therefore not of a kind to be easily condensed into a short account.

This paper is the fifth of a series (of which notices have from time to time appeared in Nature) in which I have endeavored to

* Abstract of a paper read before the Royal Society, on December 18, 1879.

trace the various effects on the configuration of a planet and satellite, which must result from tidal friction—the tides in the planet being either a bodily distortion or oceanic. The investigations are, I think, not without interest as a branch of pure dynamics, but this side of the subject is too complicated to be made intelligible without mathematical notation, and it would occupy too much space to explain the methods of treatment.

There is, however, another side of the subject, which must, I think, attract notice, or at least criticism, and this is the applicability of the results of analysis to the history of the earth and of the other planets.

We know that no solids are either perfectly rigid or perfectly elastic, and that no fluids are devoid of internal friction, and therefore the tides raised in any planet, whether consisting of oceanic tides or of a bodily distortion of the planet, must be subject to friction. From this it follows that the dynamical investigations must be applicable to some extent to actual planets and satellites. For myself, I believe that it gives the clue to the history of the system, but of course an ample field for criticism is here opened.

The investigation is intended to be more especially applicable to the case of the earth and moon, and therefore, instead of planet and satellite, the expressions earth and moon are used.

The effect of tidal friction upon the eccentricity and inclination of the lunar orbit here affords the principal topic. The obliquity of the ecliptic, the diurnal rotation of the earth, and the moon's periodic time were considered in a paper read before the Royal Society on December 19, 1878, and which will appear in the Philosophical Transactions for 1879.

The present paper completes (as far as I now see) the main investigation for the case of the earth and moon, and therefore it is now possible to bring the various results to a focus.

It appears then, that when we trace backward in time the changes induced in the system of the earth and moon by tidal friction, we are led to an initial state which is defined as follows:—

The earth and moon are found to be initially nearly in contact; the moon always opposite the same face of the earth, or moving very slowly relatively to the earth's surface; the whole system rotating in from two to four hours, about an axis inclined to the normal to the ecliptic at an angle of $11^\circ\ 45'$, or somewhat less; and the moon moving in a circular orbit, the plane of which is nearly coincident with the earth's equator.

This initial configuration suggests that the moon was produced by the rupture, in consequence of rapid rotation or other causes, of a primeval planet, whose mass was made up of the present earth and moon. The coincidence is noted in the paper, that the shortest period of revolution of a fluid mass of the same mean density as the earth, which is consistent with an ellipsoidal form of equilibrium, is two hours twenty-four minutes; and that if the moon were to revolve about the earth with this periodic time, the surfaces of the two bodies would be almost in contact with one another.

The rupture of the primeval planet into two parts is a matter of speculation, but if a planet and satellite be given in the initial configuration above described, then a system bearing a close resemblance to our own, would necessarily be evolved under the influence of tidal friction.

The theory postulates that there is not sufficient diffused matter to materially resist the motions of the moon and earth through space. Sufficient lapse of time is also required. In a previous paper I showed that the minimum time in which the system could have degraded from one initial state, just after the rupture into two bodies, down to the present state, if fifty-four millions years. The time actually occupied by the changes would certainly be much longer.

It appears to me that a theory, reposing on a *vera causa*, which brings into quantitative correlation the lengths of the present day and month, the obliquity of the ecliptic and the inclination and eccentricity of the lunar orbit, must have considerable claims to acceptance.

It was stated that the periodic times of revolution and rotation of the moon and earth might be traced back to a common period of from two to four hours. In a previous paper the common period was found to be a little over five hours in length; but that result was avowedly based on a partial neglect of the sun's attraction. In this paper certain further considerations are adduced, which show that, while the general principle remains intact, yet the common period of revolution of the earth and moon must initially have been shorter than five hours to an amount which is uncertain, but is probably large. The period of from two to four hours is here assigned, because it is mechanically impossible for the moon to revolve about the earth in less than two hours, and it is uncertain how the rupture of the primeval planet took place.

But if tidal friction has been the agent by which the earth and moon have been brought into their present configuration, then similar changes must have been going on in the other bodies which make up the solar system. I will therefore make a few remarks on the other satellites and planets.

In the first place it is in strict accordance with the theory, that the moon should always present the same face toward the earth. Helmholtz, was, I believe, the first who suggested tidal friction as the cause of the reduction of the moon's axial rotation to identity with her orbital motion. It is interesting to note in this connection that the telescope seems to show that the satellites of Jupiter, and one at least of the satellites of Saturn, also have the same peculiarity.

The process by which tidal friction brings about the changes in the configuration of a planet and satellite is a destruction of energy (or rather its partial conversion into heat within the planet, and partial redistribution), and a transference of angular momentum from that of planetary rotation to that of orbital revolution of the two bodies about their common center of inertia.

Now a large planet has both more energy of rotation and more angular momentum; hence it is to be expected that large planets should proceed in their changes more slowly than small ones.

Mars is the smallest of the planets, which are attended by satellites, and it is here alone that we find a satellite revolving faster than the planet rotates. This will also be the ultimate fate of our moon, because after the joint lunar and solar tidal friction has reduced the earth's rotation to an identity with the moon's orbital motion, the solar tidal friction will continue to reduce it still further, so that the earth will rotate faster than the moon revolves.

Before, however, this can take place with us, the moon must recede to an enormous distance from the earth, and the earth must rotate in forty or fifty days instead of in twenty-four hours. But the satellites of Mars are so small, that they would only recede a very short way from the planet, before the solar tidal friction reduced the planet's rotation below the satellite's revolution. The rapid revolution of the inner satellite of Mars may then, in a sense, be considered as a memorial of the primitive rotation of the planet round its axis.

The planets Jupiter and Saturn are very much larger than the earth, and here we find the planets rotating with great speed, and the satellites revolving with short periodic times. The inclinations of the orbits of Jupiter's satellites to their "proper planes" are very interesting from the point of view of the present theory.

The Saturnian system is much more complex than that of Jupiter, and it seems partially in an early stage of development and partially far advanced.

The details of the motions of the satellites are scarcely well enough known to afford strong arguments either for or against the theory.

I have not as yet investigated the case of a planet or star attended by several satellites, but perhaps future investigations may throw further light both on the case of Saturn, and on the whole solar system itself.

The celebrated nebular hypothesis of Laplace and Kant supposes that a revolving nebula detached a ring, which ultimately became consolidated into a planet or satellite, and that the central portion of the nebula continued to contract, and formed the nucleus of the sun or planet. The theory now proposed is a considerable modification of this view, for it supposes that the rupture of the central body did not take place until it was partially consolidated, and had attained nearly its present dimensions.

I do not pretend, in these remarks, to have thoroughly discussed the cases of the other planets, and have only drawn attention to a few salient features; in the paper itself the subject is considered at greater length. It will, however, I think, be admitted that the theory agrees with some remarkable facts in the solar system.—*Nature*, Jan. 8.

2. *Earthquakes and the Planets.*—Mr. J. Delauney has presented to the Paris Academy of Sciences some new results

obtained from a study of Perrey's tables of earthquakes from 1750 to 1842. He finds two groups of Maxima, commencing in 1759 and 1756 respectively, each with a period of about twelve years; and two other groups, commencing in 1756 and 1773 respectively, with a period of about twenty-eight years. He remarks that those of the first two groups coincide with the times when Jupiter reaches the mean longitude of 265° and 135°; while those of the last two coincide with the times when Saturn reaches the same longitudes; whence he infers that terrestrial earthquakes have a maximum when these planets are in the mean longitudes mentioned. Delauney attributes the increased number of earthquakes in winter which Perrey has found to reach a maximum in November, to the passage of the earth at that time through swarms of meteors; and in like manner supposes the influence of Jupiter and Saturn to be due to their passing through meteor streams situated in mean longitudes 135° and 265°. As a consequence of this he ventures to predict an increased number of earthquakes in the years 1886, 1891, 1898, 1900, etc. C. G. R.

3. *The Problem of the Euripus.*—The tides in this narrow strait between Eubœa and the mainland of Greece, have from classic times been a scientific puzzle, for which a solution has been recently suggested by M. Forel, in a paper before the Paris Academy of Sciences. The currents through the strait are sometimes "regular" and sometimes "irregular." When "regular," the direction changes *four* times in the lunar day. When "irregular," the changes number from *eleven* to *fourteen* or even more in a lunar day. The current is "irregular" from the 7th to 13th and from the 21st to 26th day of the lunar month, or at the times of *quadrature*, and "regular" the rest of the time, or about the *syzygies*.

M. Forel attributes the "regular" tides to the ordinary tides of the Ægean Sea, which would be stronger at the syzygies. The "irregular" tides he thinks are due to *seiches* in the channel of Talauda (which forms a nearly closed lake to the northwest of Euripus), these prevailing over the weaker Ægean tides of the quadratures. From a ten years study of the seiches of Lake Leman, M. Forel has derived a formula to represent their time of vibration. This formula, ($t=\frac{2l}{\sqrt{gh}}$, in which $l=$ length and $h=$ depth of the lake), when applied to the channel of Talauda, whose length is 115 kilometers and maximum depth 200 fathoms, gives for the time of vibration 122, 100, and 86 minutes, according as the mean depth is taken at 100, 150 or 200 fathoms. These results agree well with the observation of eleven to fourteen tides per day, (which would give from 135 to 106 minutes for a single vibration), and would seem to confirm M. Forel's idea. C. G. R.

4. *The American Ephemeris and Nautical Almanac for the year* 1882. Washington, 1879.—In this volume of the National Ephemeris, Professor Newcomb has introduced several important changes, which were suggested by him and approved by a committee of the National Academy of Sciences.

The volume is now made to consist of three parts: 1st, the ephemeris for the meridian of Greenwich; 2d, the ephemeris for the meridian of Washington; 3d, predictions of phenomena to be observed, with data for their computation. The principal additions consist of the mean places of about 180 stars, making 383 in all, for the convenience of field astronomers, more complete data for eclipses, data about the transit of Venus, and largely increased information about the satellites of the planets.

5. *Auroræ: their Characters and Spectra;* by J. RAND CAPRON. F.R.A.S. 207 pp. 4to. London, 1879. (E. & F. N. Spon.)—The subject of the Aurora Borealis is one of popular as well as scientific interest, and this work by Mr. Capron not only presents it in a way to be entertaining to the general reader but also of great value to the scientific worker. After a few pages devoted to the historical part of the subject, the author goes on to describe in detail a number of specific auroral displays of especially remarkable character, and with them the various attendant phenomena. The latter half of the work is devoted to the discussion of the spectrum of the aurora, and the various magneto-electric experiments that have been made which tend to throw light upon its cause. The various theories that have been advanced to account for the aurora are mentioned. The book is published through the private liberality of Mr. Capron, and in respect to the number and beauty of the chromos and other illustrations deserves very high praise.

V. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *United States Mensuration Surveys.*—The necessity for an organization in the Government to have charge and execution of all geodetic, geographical and topographical work of the whole country, in accordance with the recommendation of the Academy of Sciences to Congress at the last regular session, becomes more and more apparent the more closely the subject is studied. At the present time nearly all the States have their Geological Surveys so far advanced that nothing further can be done until these States are completely mapped by triangulation and topography on a sufficiently large scale. Such a survey is of great importance to every one owning an acre of ground; by it all boundary disputes could easily be settled; every farmer would have a complete survey of his farm, with all undulations of surface given and its relations to the adjacent farms, streams, woodlands and hills. There is no question that by the concentration of the classes of work referred to in one organization, with its unity of purpose and action, great economy would result in the execution of the work over a given area, with the certainty that every separate area so surveyed would ultimately join as a part of the whole with the accuracy attainable only by scientific processes of precision.

It is quite certain that large areas of the public domain, unfit for purely agricultural purposes, could be more economically and accurately surveyed, for purposes of sale, by triangulation than

by the present system (so admirably adapted to agricultural lands), with the additional advantage of obtaining an accurate map without additional cost.

The triangulation part of the Geodetic Survey, with the reconnaissance for progressive work, executed by the Coast Geodetic Survey now covers one-third of Maine, two-thirds of New Hampshire, one-third of Vermont, one-half of Massachusetts, one-half of Connecticut, two-thirds of New Jersey, one-quarter of Pennsylvania, one-quarter of Maryland, one-third of Virginia, one-quarter of North Carolina, South Carolina, Georgia and Alabama, one-sixth of Mississippi, one-sixth of Tennessee, one-fifth of Kentucky, one-tenth of Ohio, one-tenth of Indiana, one-tenth of Illinois, one-sixth of Missouri, one-fifth of Wisconsin, one-sixth of Colorado, one-sixth of Nevada and Utah, one-fifth of California; and the triangulation of the Lake Survey is complete along the American shores of Lakes Ontario, Erie, Huron, Michigan and Superior, and across Michigan between Lakes Erie and Michigan. By joining this smaller work with that first mentioned, there will be formed a complete basis for the extension of the triangulation over every State and Territory except Alaska. It thus appears that no new organization is required, but simply the extension of one already in existence, familiar with the work, and conducted by experienced and skilled persons.

The ultimate cost of such a survey is sometimes stated as an objection to a system so complete, but this cost is greatly exaggerated in popular opinion. In the older States where many details, such as houses, roads, clearings, villages and towns exist, the average cost, as nearly as can be computed by past experience, would not, except in cases of the large towns, exceed seven cents per acre. This expense should be divided between the General Government and the State, the Government executing the triangulation and that part of the topography required to delineate the characteristic forms of the country, including the streams; the State to execute the remainder of the topographical detail required for its own purposes. In such case the cost to the State would not exceed three cents per acre. To this an exception must be made in cases of large towns, where the surveys might be required on large scales; the cost would then be determined by the scale of the work.

It is to be hoped, in consideration of the vast importance to the country of a comprehensive survey of its area, that this session of Congress will not close without the passage of a law carrying fully into effect the plan recommended by the National Academy of Sciences to Congress at its last regular session, meeting in this respect the just requirements of the public service, with a new departure and a new hope of increased usefulness to our whole people. EDS.

2. *The Arctic Voyages of Adolf Erik Nordenskiöld*, 1858–1879, with illustrations and maps. 447 pp. 8vo. London, 1879. (Macmillan & Co.)—The general interest that has recently been

excited by the remarkably successful voyage of Professor Nordenskiöld, around the north coast of Asia, cannot fail to have awakened a desire for further information in regard to his earlier Arctic explorations. This desire will be satisfied by the present volume, prepared by Mr. Alex. Leslie, of Aberdeen. It opens with an autobiographical sketch of Professor Nordenskiöld; then follow accounts of the Swedish Arctic Expeditions of 1858, 1861, 1864, 1868, 1873, also of the voyage to Greenland in 1870, in which the large masses of native iron were discovered, the voyages to the Yenissej in 1875, and again in 1876, and finally a partial account of the Northeast Passage expedition of 1878–1879, in the Vega. The accounts are intended to be popular, only occasional brief references to the scientific results of the expedition being introduced, but they are well written and fully illustrated. The book is a valuable addition to the many fascinating stories of Arctic exploration, and still more is a worthy tribute to one of the ablest explorers who has entered that perilous field.

3. *Chart of the Magnetic Declination of the United States;* by J. E. Hilgard. Washington, 1879. (U. S. Coast and Geodetic Survey, Carlile P. Patterson, Superintendent.—Appendix No. 21, Report of 1876.)—This chart of the magnetic declination of the United States for 1875, by Professor J. E. Hilgard, is mainly based upon the Coast Survey observations up to 1877, together with observations made under his direction at 200 stations between 1872–77, at the charge of the Bache Fund. In addition to these two principal sources, use has also been made of observations taken in various surveys by the U. S. Engineers and under the direction of the General Land Office. The reduction of the observations to a common date has been based on the researches of Mr. C. A. Schott on the secular variation of the magnetic declination in the United States.

4. *On the probable Temperature of the Primordial Ocean of our Globe;* by Robert Mallet, F.R.S., F.G.S.—According to the latest hypotheses as to the quantity of water on the globe, its pressure, if evenly distributed, would be equal to a barometric pressure of 204·74 atmospheres. Accordingly water, when first it began to condense on the surface of the globe, would condense at a much higher temperature than the present boiling-point under ordinary circumstances. The first drops of water formed on the cooling surface of the globe may not impossibly have been at the temperature of molten iron. As the water was precipitated, condensation of the remaining vapor took place at a lower temperature. The primordial atmosphere would be more oblate and less penetrable by solar heat than the present, and the difference of temperature between polar and equatorial regions would be greater; so that, in the later geological times, ice may have formed in the one, while the other was too hot for animal or vegetable life.—*Phil. Mag.*, Jan., 1880.

5. *How to Work with the Microscope.* 5th edition, enlarged and revised. 518 pp. 8vo. Philadelphia, 1880 (Presley Blak-

iston, formerly Lindsay & Blakiston).—This work by LIONEL S. BEALE, F.R.S., President of the Royal Microscopical Society, is an invaluable contribution to the *English* literature on the microscope. The well known 4th edition has been completely remodeled; over 100 pages of new matter and 150 engravings have been added. The present edition is not only a text book but an encyclopedia of the microscope. Of the new material published we notice: (1) by Prof. Gulliver, F.R.S., 41 figures of plant crystals with original notes; (2) by Mr. Wenham, F.R.M.S., practical suggestions connected with the construction of object glasses; (3) by Mr. H. C. Sorby, F.R.S., additional matter on spectro-microscopy; (4) by Mr. Frank Rutley, of the Geological Survey, concise, clear and admirable directions for the microscopic examina- of rocks, minerals and fossils, illustrated by 39 figures. That portion of the last edition on photography by Dr. Maddox, has been revised by Dr. Clifford Mercer, who mentions a number of recent improvements and adds a *complete* list of memoirs on the application of photography to the microscope. The entire work bears evidence of much laborious care on the part of Dr. Beale in its revision. It is eminently practical in its methods; a self-help to the beginner and instructive to the more advanced student of the microscope. C. A. A.

6. *The American Monthly Microscopical Journal.* Editor and Publisher, ROMYN HITCHCOCK, F.R.M.S. Vol. i, No. 1, January, 1880. New York.—The new monthly is in fact a continuation of the Quarterly, which was previously carried on under the same editor. The first number of twenty pages contains articles on new species of Ophrydium; on the Amplifiers of Zeiss; on fresh-water Algæ; on a method of making sections of insects and their appendages; on the classification of Rhizopods; with also editorial notes, correspondence, etc.

7. *The School of Mines Quarterly;* Vol. i, No. 1, New York, 1880.—This new Journal is issued quarterly under the auspices of the Chemical and Engineering Societies of Columbia College. It promises to occupy a creditable position among undergraduate periodicals. The first number contains the following articles: The pedometer as a surveying instrument, by Prof. H. S. Munroe; Coffee and its adulterations, by F. Weichmann; Fire-brick and Terra cotta, by A. M'L. Parker; Chloral, by A. P. Hallock; Building Stones, I, by J. L. Greenleaf; with also notes on Mineralogy by C. A. Colton, E.M. and on Physics by M. C. Ihlsing, Ph.D.

8. *Catalogue of Diatomaceæ*, by FREDERICK HABIRSHAW, F.R.M.S. (New York: Romyn Hitchcock).—This catalogue is designed to be a complete index to all the published literature describing or figuring the Diatomaceæ. It is stated that the species will be arranged alphabetically, under the proper genera referring to every description in chronological order. The work is to appear in four parts in large octavo, and its unquestioned value will doubtless be appreciated by all workers in this field.

9. *Treatise on Fuel, scientific and practical;* by ROBERT GALLOWAY, M.R.I.A., F.C.S. 136 pp. 8vo. London, 1880. (Trübner & Co.)—This little book contains, in a compact form, the more important facts in regard to the properties of the different kinds of fuels, their heating power and the calorimetric methods by which it is determined; also a chapter on pyrometers, and another on the Siemens regenerative gas furnace. The work is arranged with a view to being used in instruction, while at the same time valuable to the practical manufacturer.

10. *Petroleum.*—Mr. C. A. ASHBURNER, in a lecture in the Franklin Institute course, upon the subject of petroleum, stated that he estimated that Pennsylvania, from the discovery of oil by Col. Drake, in 1859, to the end of 1879, had produced in the aggregate 133,262,639 barrels of crude oil, from the sale of which the State has realized $340,709,672. The theory that the Pennsylvania oils are derived entirely from the decomposition of the vegetable and animal life of the Devonian age, and that the oil sands are but reservoirs holding the oil, Mr. Ashburner thinks established beyond a doubt by facts gathered from the oil miner.

OBITUARY.

ALEXANDER SADEBECK, Professor of Mineralogy at the University of Kiel, and author of many papers upon mineralogical subjects, died on the 9th of December, 1879, at the age of thirty-six.

Report of the Entomologist, Charles V. Riley, M.A., Ph.D. 52 pp. 8vo, with 7 plates. Washington, 1879 (Report of Department of Agriculture for 1878).

Journal of the Cincinnati Society of Natural History, vol. ii, no. 2, July, 1879. Contents:—Annual Address, by V. T. Chambers; notes on some new or little known North American Limnæidæ, by A. G. Wetherby; observations on birds, by Charles Dury and L. R. Freeman; description of twelve new fossil species and remarks upon others, by S. A. Miller.

Unser Sonnenkörper nach seiner physikalischen, sprachlichen und mythologischen Seite hin betrachtet von Dr. Schmidt, Rector in Gevelsberg. 60 pp. 4to. Heidelberg, 1877.

The Workshop Companion: a collection of useful and reliable recipes, rules, processes, methods, wrinkles and practical hints for the household and the shop. 164 pp. 12mo. New York, 1879.

The Palenque Tablet in the United States National Museum, Washington, D. C.; by Charles Rau. 81 pp. 4to. Washington City, 1879.

A Dictionary of the German terms used in Medicine; by George R. Cutter, M.D. 304 pp. 8vo. New York, 1879 (G. P. Putnam's Sons).

Report on the Meteorology of India, for 1877, by John Elliott. Third year. Calcutta, 1879. Quarto, pp. 230; appendix pp. 114.

Report of the administration of the Meteorological Department of India. Thin quarto.

Report on the Madras Cyclone of May, 1877, by J. Elliot, M.A. Meteorological Reporter to the Government of Bengal. Quarto, Calcutta, 1879.

Zoology for Students and General Readers, by A. S. Packard, M.D., Ph.D. 719 pp. 8vo, with numerous illustrations. New York, 1880, (Henry Holt & Company).

APPENDIX.

ART. XXI.—*The Limbs of Sauranodon, with Notice of a new Species;* by O. C. MARSH.

SINCE the first species of the present genus (*Sauranodon natans*) was described by the writer,* eight other specimens of the same group have been discovered, and are now in the Yale Museum. In three of these, the skull is preserved, but there are still no indications of teeth, so that we may consider these reptiles as entirely edentulous. The skull shows many points of resemblance to that of *Ichthyosaurus*. The vertebræ, also, are very similar to those in that genus.

In the characters of the limbs, *Sauranodon* presents some features of special interest. The anterior and posterior limbs are well developed, and adapted for swimming. These extremities are less specialized than those in any other known vertebrate above the Fishes.

In the fore paddle, the humerus alone is differentiated. Below this, the bones of the forearm, the carpals, metacarpals, and phalanges are essentially rounded, free disks, implanted in the primitive cartilage. The radius may perhaps be regarded as a partial exception, as its free margin is nearly straight, and somewhat thinner than the remaining border. There are three bones of nearly equal size in the first row below the humerus. The radius may be identified with certainty by its position. The next bone evidently corresponds to the intermedium, and the third, or outer one, to the ulna. In the succeeding row, there are four subcircular bones, and five in the next series. These represent the carpals. There are six metacarpals, and also six well developed digits, each composed of numerous phalanges, which are all free, and nearly circular in form.

In the posterior limb, the structure is essentially the same. The distal end of the femur has three distinct facets, and of these the middle one is the largest. Next below the femur, and articulating with it, are three bones which apparently represent the tibia, intermedium, and fibula, although the first alone can be determined from its shape and position. The next row contains four rounded bones; and the succeeding one,

* This Journal, vol. xvii, p. 85, Jan., 1879.

five, as shown in the cut below. These correspond to the tarsals, and in the next series are the six metatarsals. There are six digits represented in this specimen. The distal phalanges are small and circular, and are left unshaded, as their exact position has not been determined.

1.

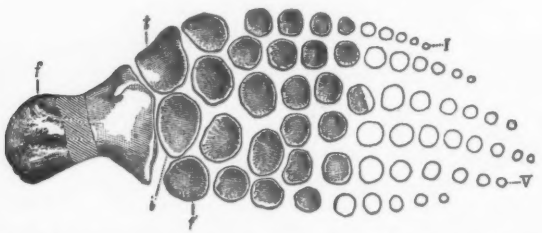


Figure 1. Left hind paddle of *Sauranodon discus*, Marsh; seen from below, one-eighth natural size; *f*, femur; *t*, tibia; *i*, intermedium; *f'*, fibula; *I*, first digit; *V*, fifth digit.

The above figure agrees essentially with the other paddles preserved, and thus may be taken to represent the typical limb in this group of reptiles. The most striking features in this Sauranodon limb are, the three bones articulating with the femur, and the six complete digits. These characters mark a stage of development below that seen in any other air-breathing vertebrate, and only approached by the limb of *Ichthyosaurus*. The transverse segmentation is distinct in the first five series, regarding the humerus and femur as the first segment, or propodial bones.* If the three bones of the second series (epipodials) are rightly interpreted, the middle one is the intermedium. Its position in the paddles of *Sauranodon* of both the known species indicates that its true place is in the segment where it is found. If so, it follows that in the process of differentiation this bone has been gradually crowded out of its original position between the marginal bones of the second, or epipodial, series into the third, or mesopodial, where we now find it.

* The need of general designations to apply to the corresponding segments alike of the anterior and posterior limbs of the air-breathing vertebrates is evident. While we have the convenient terms "Phalanges" and "Metapodials" for the distal parts of the extremities, there are no names in use for the portions above. Hence, the following are suggested:

	Anterior.	*Posterior.*
Propodial bones =	Humerus,	Femur.
Epipodial " "	Radius and Ulna,	Tibia and Fibula.
Mesopodial " "	Carpals,	Tarsals.
Metapodial " "	Metacarpals,	Metatarsals.
Phalangial " "	Finger bones,	Toe bones.

In *Ichthyosaurus*, the intermedium is not entirely excluded from the epipodial row; in *Plesiosaurus* and all other reptiles the process is essentially completed. In some Amphibians, this bone still separates the lower ends of the two specialized bones above it. *Sauranodon* marks an earlier and most interesting stage in the differentiation, and, taken in connection with the examples here cited, indicates clearly how the transition was accomplished.

The six complete digits in the limbs of *Sauranodon* is a character not before observed in any air-breathing vertebrate. Some of the Amphibians retain remnants of a sixth digit, and *Ichthyosaurus* often has, outside of the phalanges, one or more rows of marginal ossicles that probably represent lost digits. With these exceptions, the normal number of five digits is not exceeded.

Sauranodon discus, sp. nov.

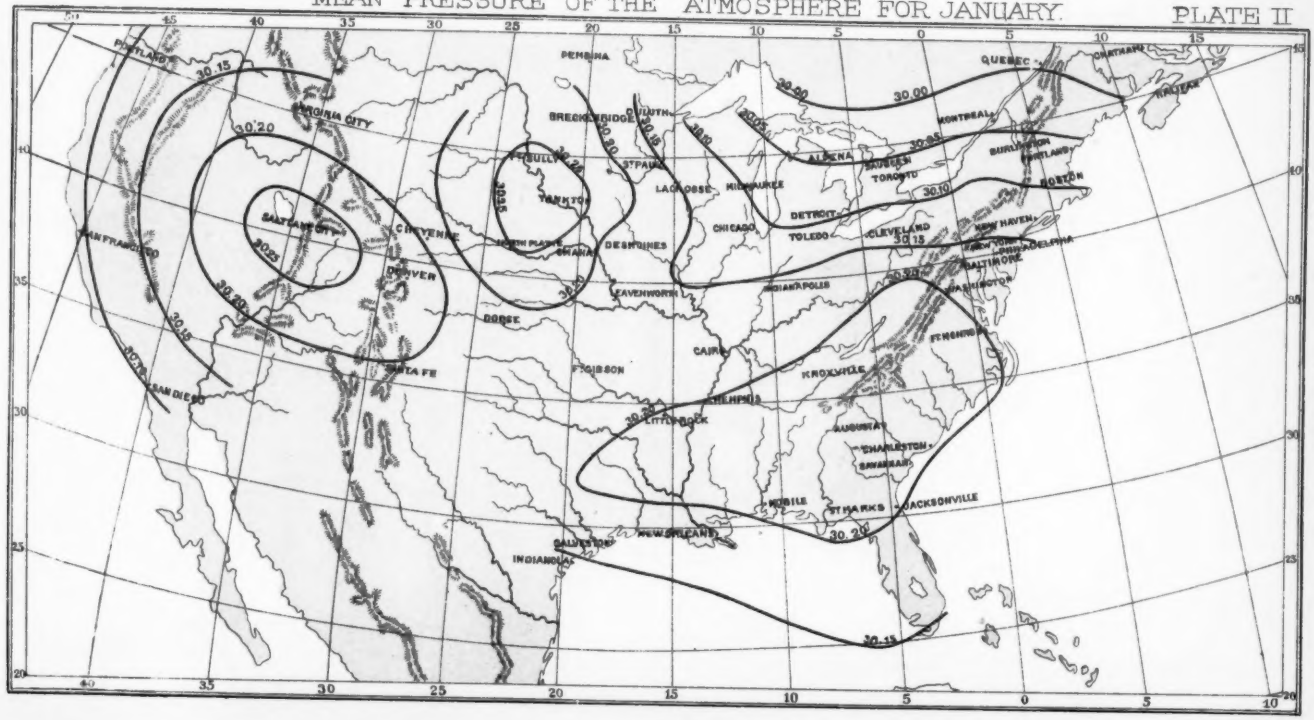
A comparison of the various specimens of *Sauranodon* now known indicates two distinct species, which may be distinguished as follows: the type species (*S. natans*) has the facial portion of the skull much elongated, and the snout slender. The vertebræ are short, and deeply concave, in fact, almost perforate. The head of the humerus is but very slightly convex. A second specimen, which agrees in its main specific characters with the type, has a subcircular coracoid, with but slight emargination.

In the species here described, which is based upon the greater portion of a skeleton, the coracoid is more deeply emarginate, and the head of the humerus rounded, nearly as much as that of the femur. The paddles, also, are broader in proportion to their size, than in the type species, and other differences are apparent.

The present specimen indicates a reptile about twelve feet in length. It is from the upper Jurassic of Wyoming, and was found in the series of marine deposits which the writer has called the Sauranodon beds. This is a well marked horizon.

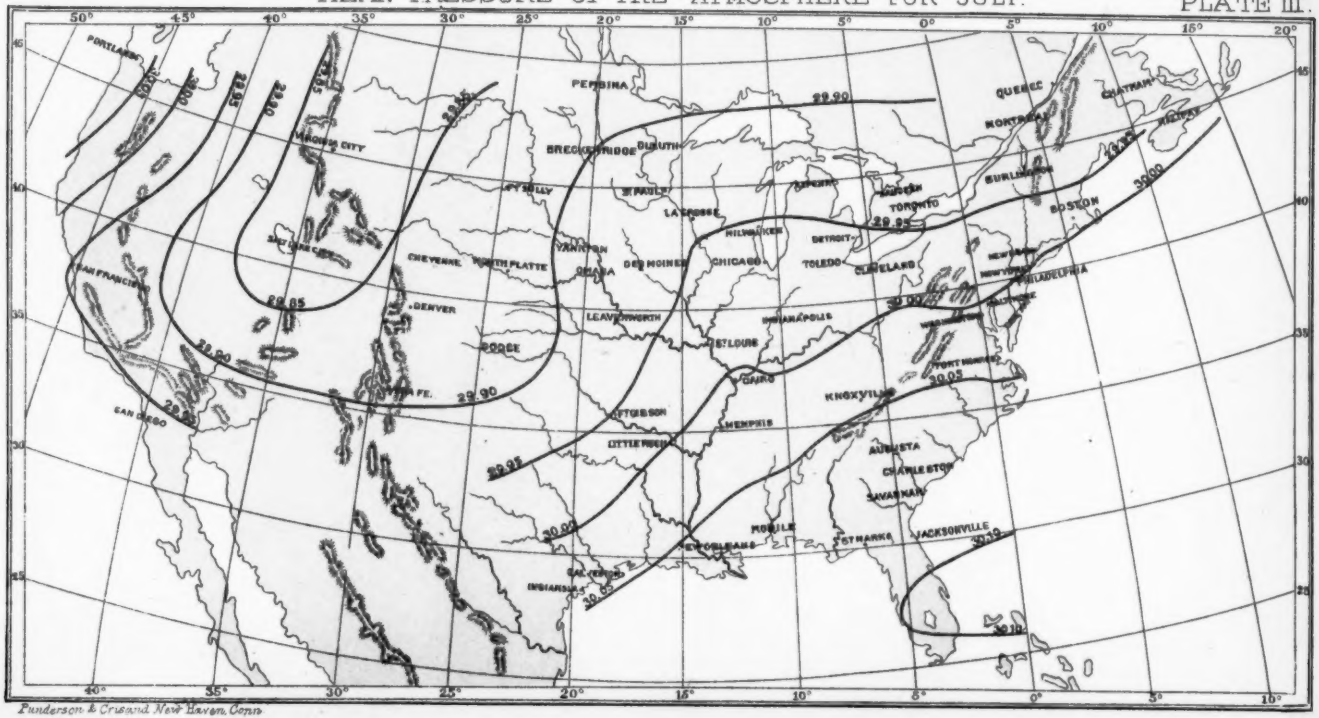
Yale College, New Haven, Jan. 24th, 1880.

MEAN PRESSURE OF THE ATMOSPHERE FOR JANUARY. PLATE II



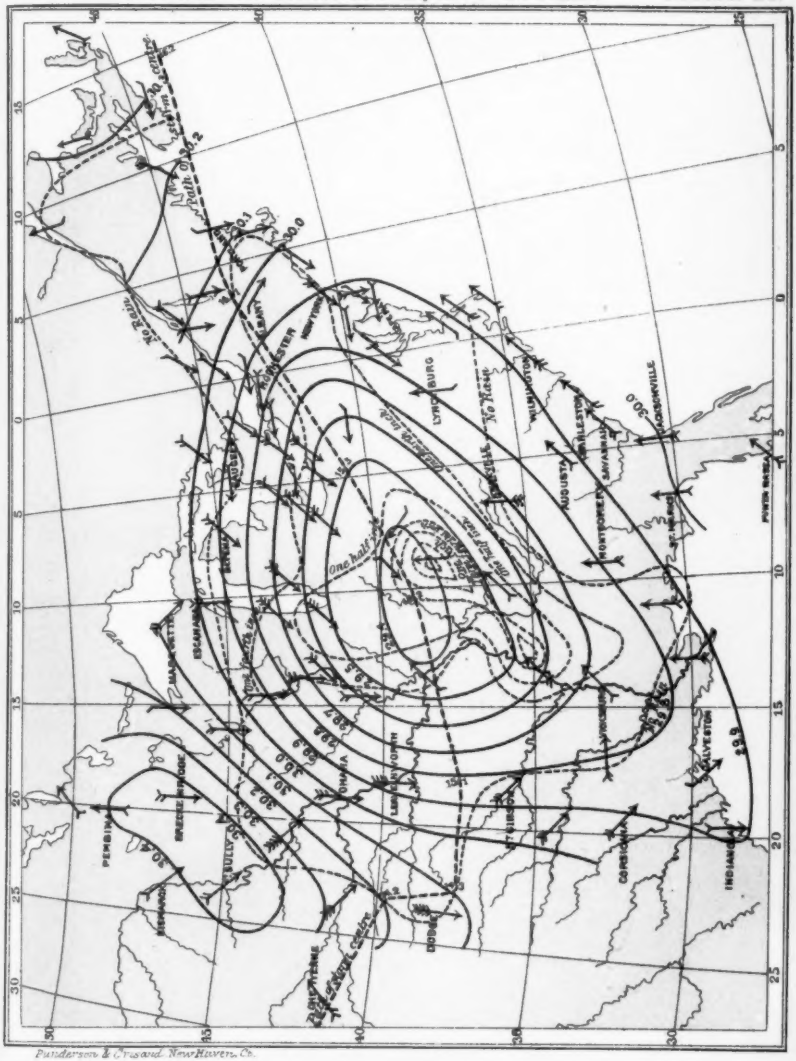
MEAN PRESSURE OF THE ATMOSPHERE FOR JULY.

PLATE III.



Sunderson & Crisand. New Haven, Conn.

STORM OF JANUARY 15, 1877-4.35 P.M. PLATE IV.



No. 24.

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45°
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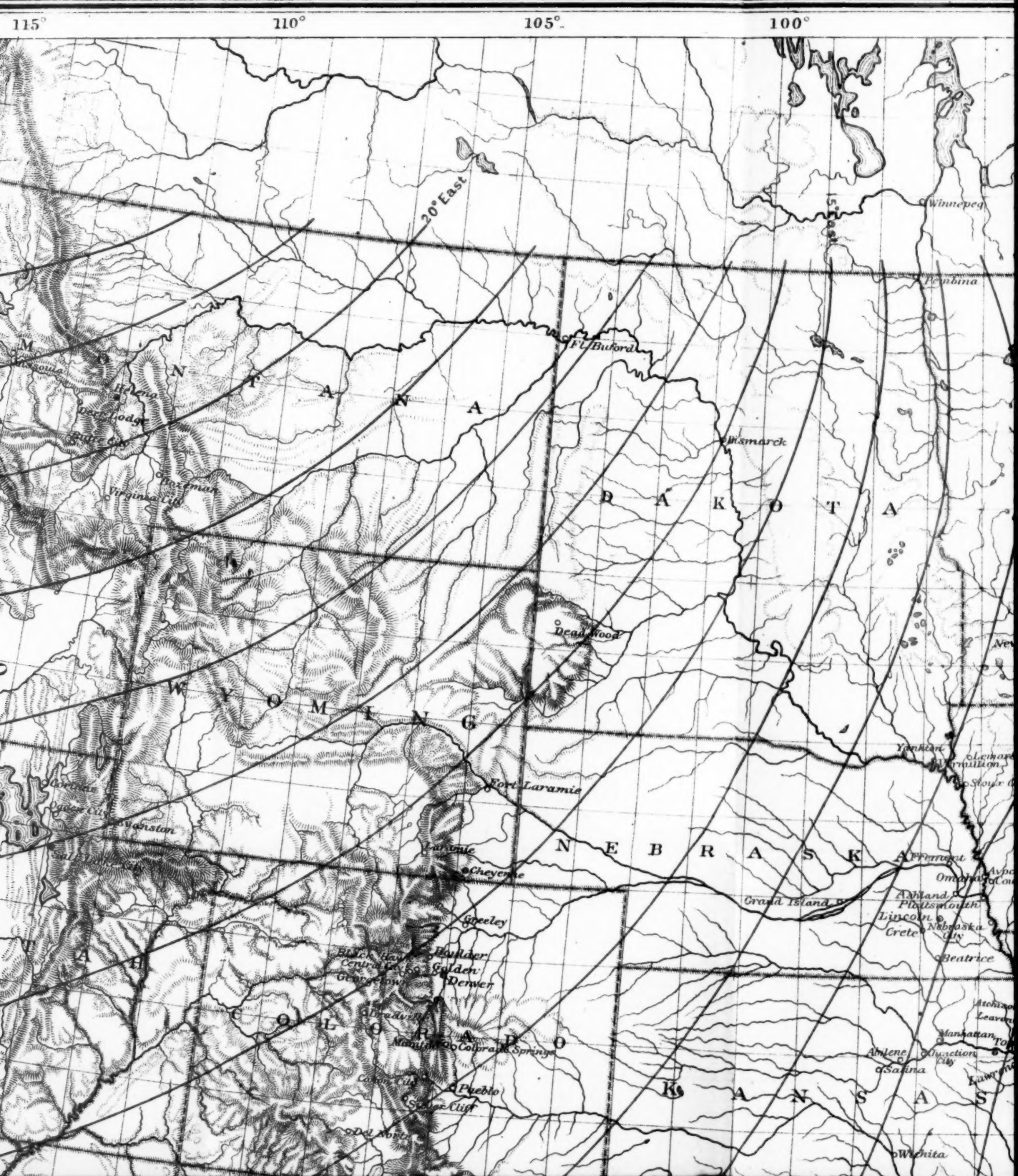
35°
BRITISH COLUMBIA
WASHINGTON
OREGON
NEVADA
Walla Walla
Boise City
Silver City
Virginia City
Gold Hill
Austin
Eureka
Hamilton
Sacramento
San Francisco
Santa Cruz
Monterey
Los Angeles
Santa Barbara
San Diego
PACIFIC

Lines of Equal Magnetic Declination in



LINES OF EQUAL MAGNETIC DECLINATION IN

THE UNITED STATES FOR THE YEAR 1875.

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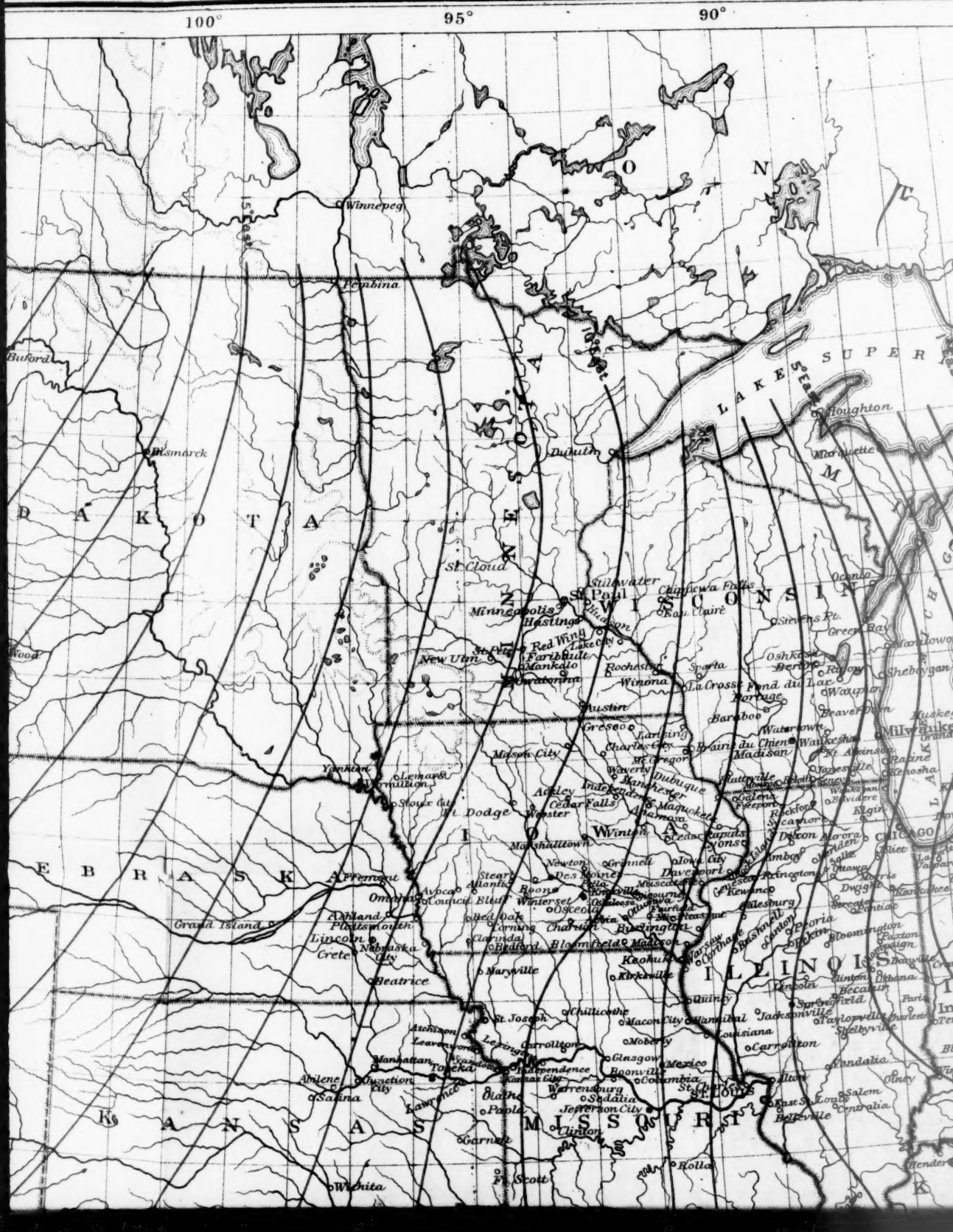

FOR THE YEAR 1875.

80°
75°
LAKE HURON
GEORGIAN BAY
LAKE ONTARIO
LAKE ERIE
Toronto
Hamilton
Buffalo
Rochester
Ottawa
Kingston
Montreal
Pembroke
Detroit
Windsor
Cleveland
Pittsburgh
Allegheny
PENNSYLVANIA
OHIO
CINCINNATI
WEST VIRGINIA
Louisville
KENTUCKY
VIRGINIA
Richmond
Danville
Salem
Lynchburg
Harrisonburg
Charlottesville
Fredericksburg
Petersburg
Norfolk
Portsmouth
Suffolk
Hampton
Newport News
Williamsburg
Wilmington
Baltimore
Washington
Philadelphia
Harrisburg
Scranton
Wilkesbarre
Albany
Troy
Utica
Syracuse
Oswego
Binghamton
Ithaca
Elmira
Corning
Jamestown
Erie
Meadville
Titusville
Oil City
Franklin
Warren
Youngstown
Akron
Canton
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Zanesville
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Springfield
Dayton
Xenia
Chillicothe
Portsmouth
Ashland
Huntington
Parkersburg
Charleston
Logan
Lancaster
Athens
Pomeroy
Gallipolis
Ironton
Maysville
Frankfort
Lexington
Versailles
Harrodsburg
Danville
Shelbyville
Frankfort
Georgetown
Cynthiana
Owensboro
Hopkinsville
Bowling Green
Abingdon
Wytheville
Christiansburg
Lynchburg
Farmville
Hanover
Liberty
Salem
Roanoke
Staunton
Winchester
Martinsburg
Hagerstown
Frederick
Gettysburg
Carlisle
Lancaster
Reading
Pottsville
Easton
Bethlehem
Allentown
Harrisburg
Lebanon
Chambersburg
Hagerstown
Cumberland
Uniontown
Connellsville
Greensburg
Johnstown
Altoona
Bellefonte
Lock Haven
Williamsport
Towanda
Wyalusing
Montrose
Carbondale
Honesdale
Port Jervis
Middletown
Newburgh
Poughkeepsie
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Troy
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Saratoga
Glens Falls
Whitehall
Plattsburg
Rouses Point
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Beauharnois
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Utica
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Cazenovia
Auburn
Seneca Falls
Geneva
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Rochester
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Niagara Falls
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Bradford
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Albion
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Lockport
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Huron
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Galion
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Delaware
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Galion
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Findlay
Fostoria
Tiffin
Bellevue
Clyde
Sandusky
Port Clinton
Put-in-Bay
Kelleys Island
Marblehead

70°
65°
NEW BRUNSWICK
MAINE
NEW HAMPSHIRE
BOSTON
Quebec
St. John
Annapolis
Portland
Portsmouth
Newburyport
Gloucester
Salem
Lynn
Plymouth
Fall River
Nantucket
Hartford
New Haven
Bridgeport
Stamford
Brooklyn
Princeton
Trenton
Burlington
Montpelier
St. Albans
Richmond
Sherbrooke
Levis
Fredericton
Chatham
Calais
Bangor
Augusta
Biddeford
Dover
Concord
Lowell
Worcester
Springfield
Providence
Norwich
Waterbury
Meriden
Middletown
Yarmouth
45°
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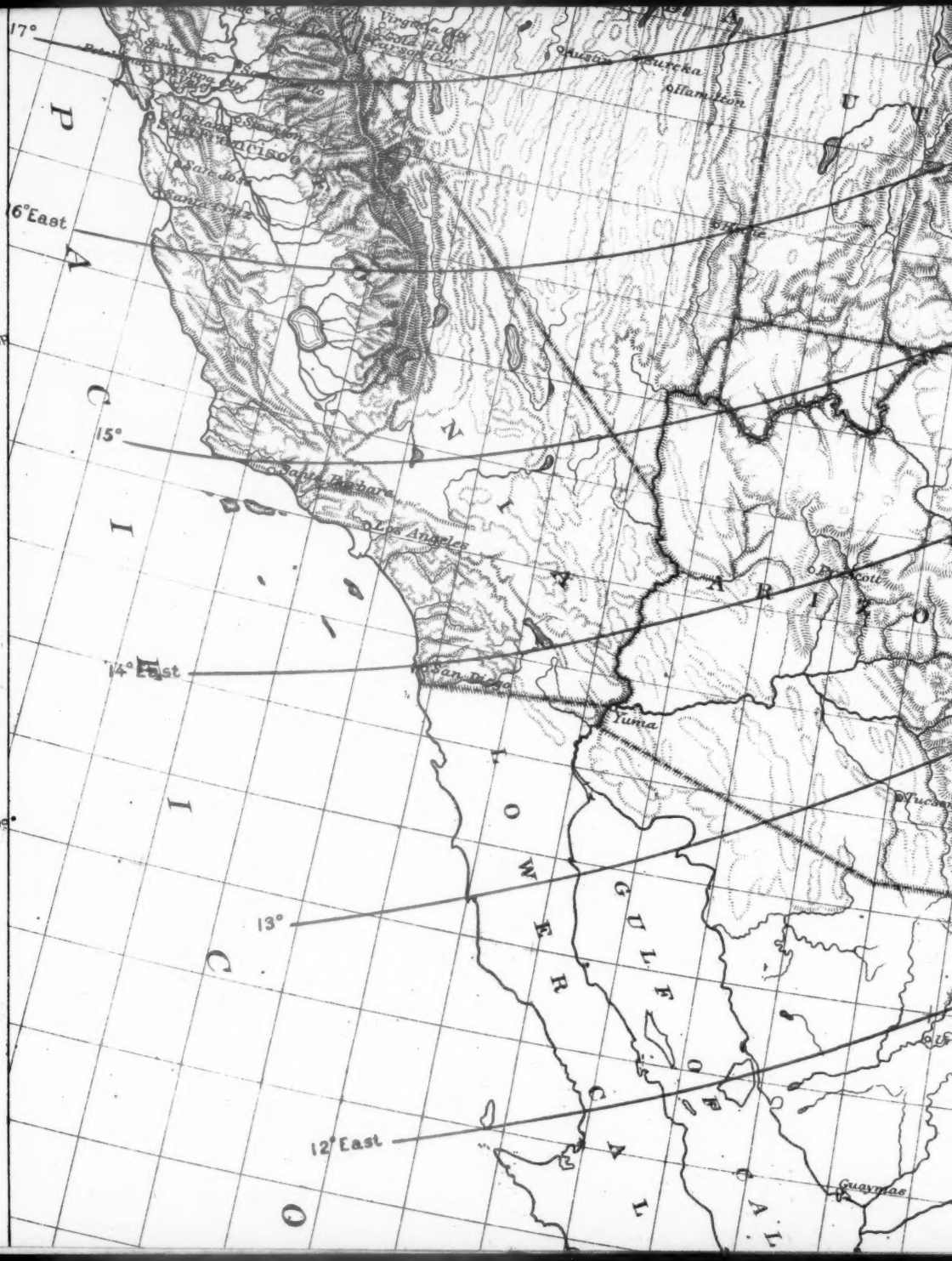
ATLANTIC OCEAN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Santa Cruz
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Los Angeles
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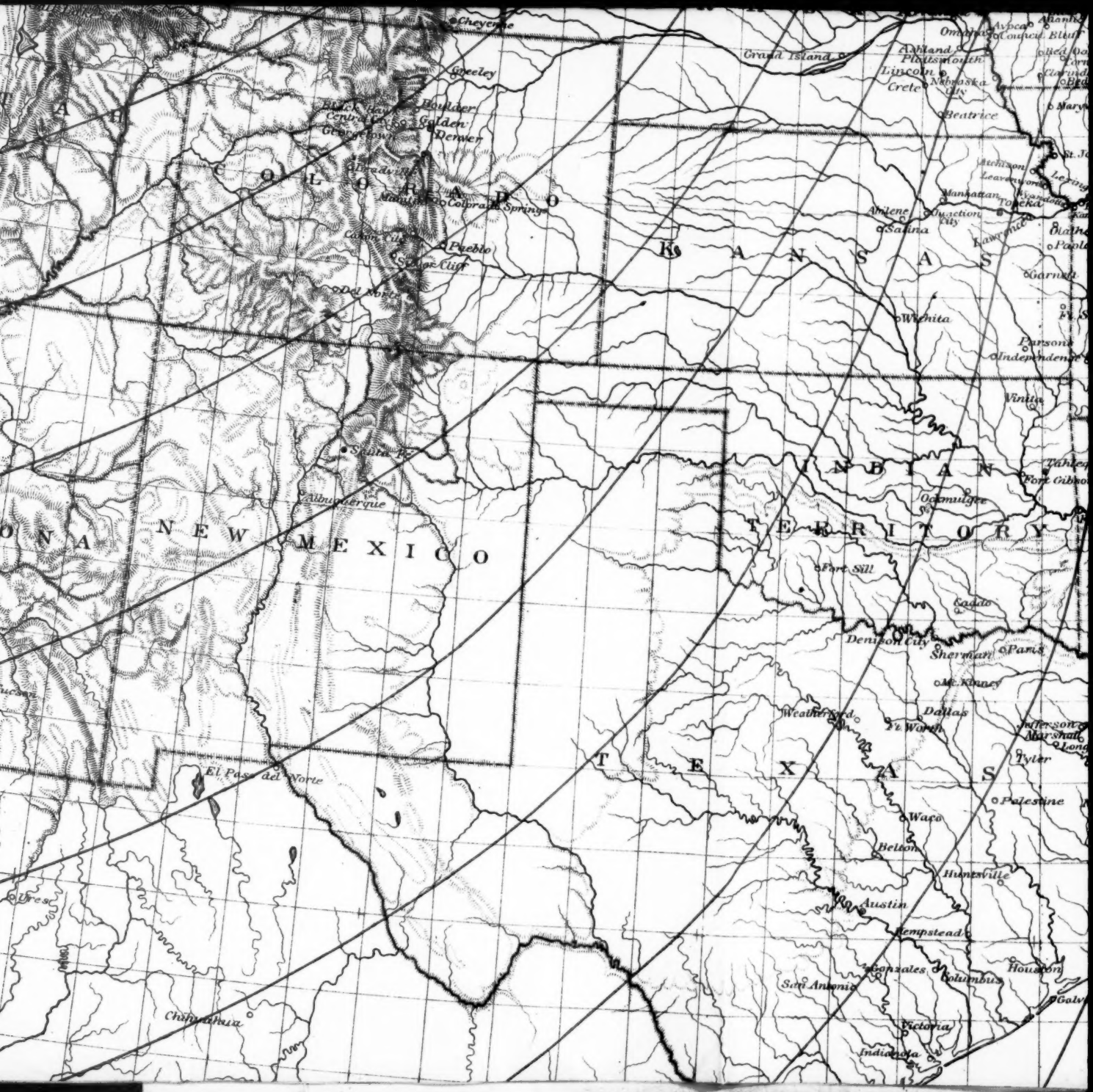
Yuma
Prescott
Guaymas
GULF OF CALIFORNIA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Vinita
Tahlequah
Fort Gibson
Okmulgee
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Fort Sill
Caddo
Denison City
Sherman
Paris
Mt. Pleasant
Weatherford
Dallas
Ft. Worth
Jefferson
Marshall
Tyler
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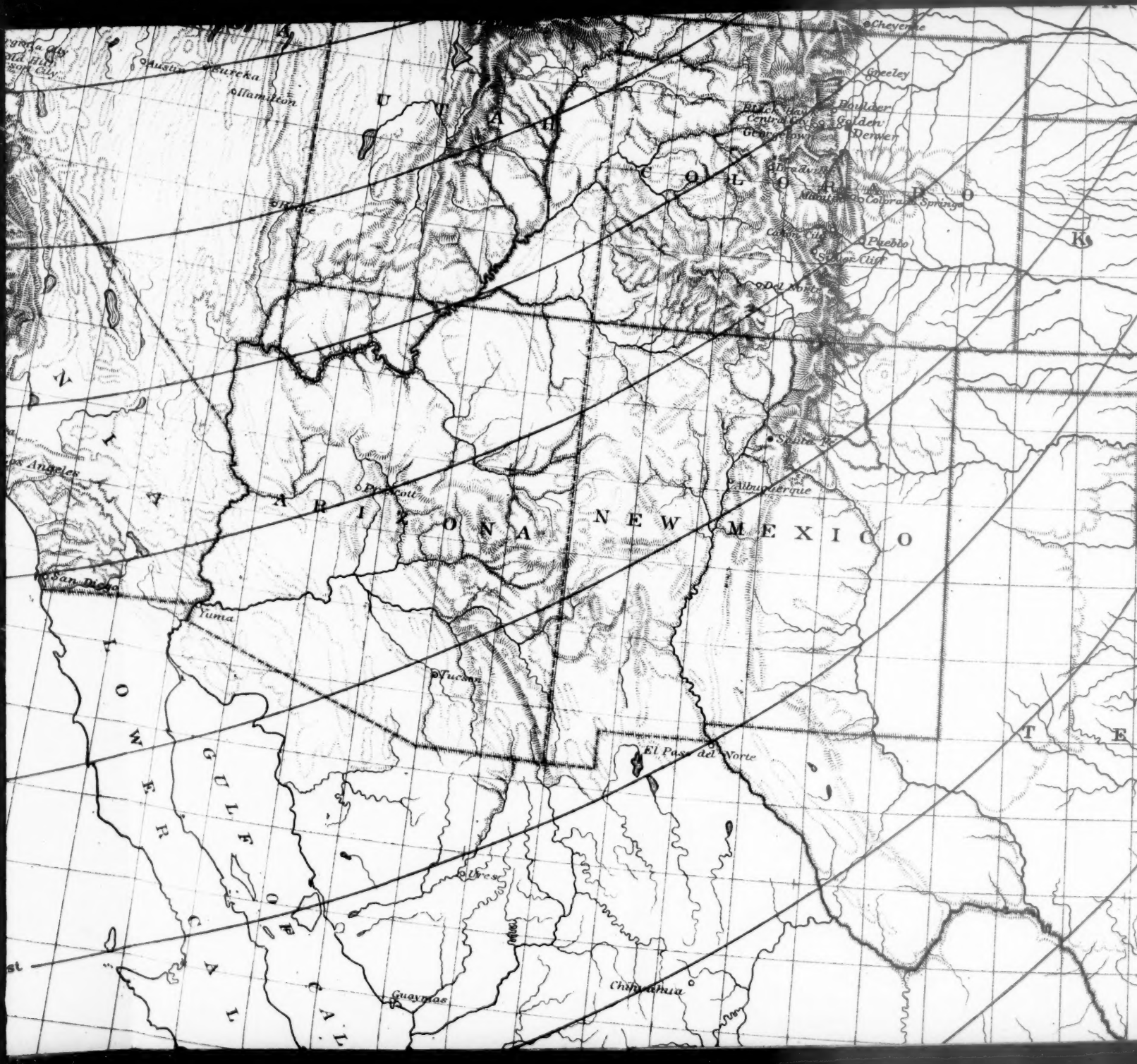
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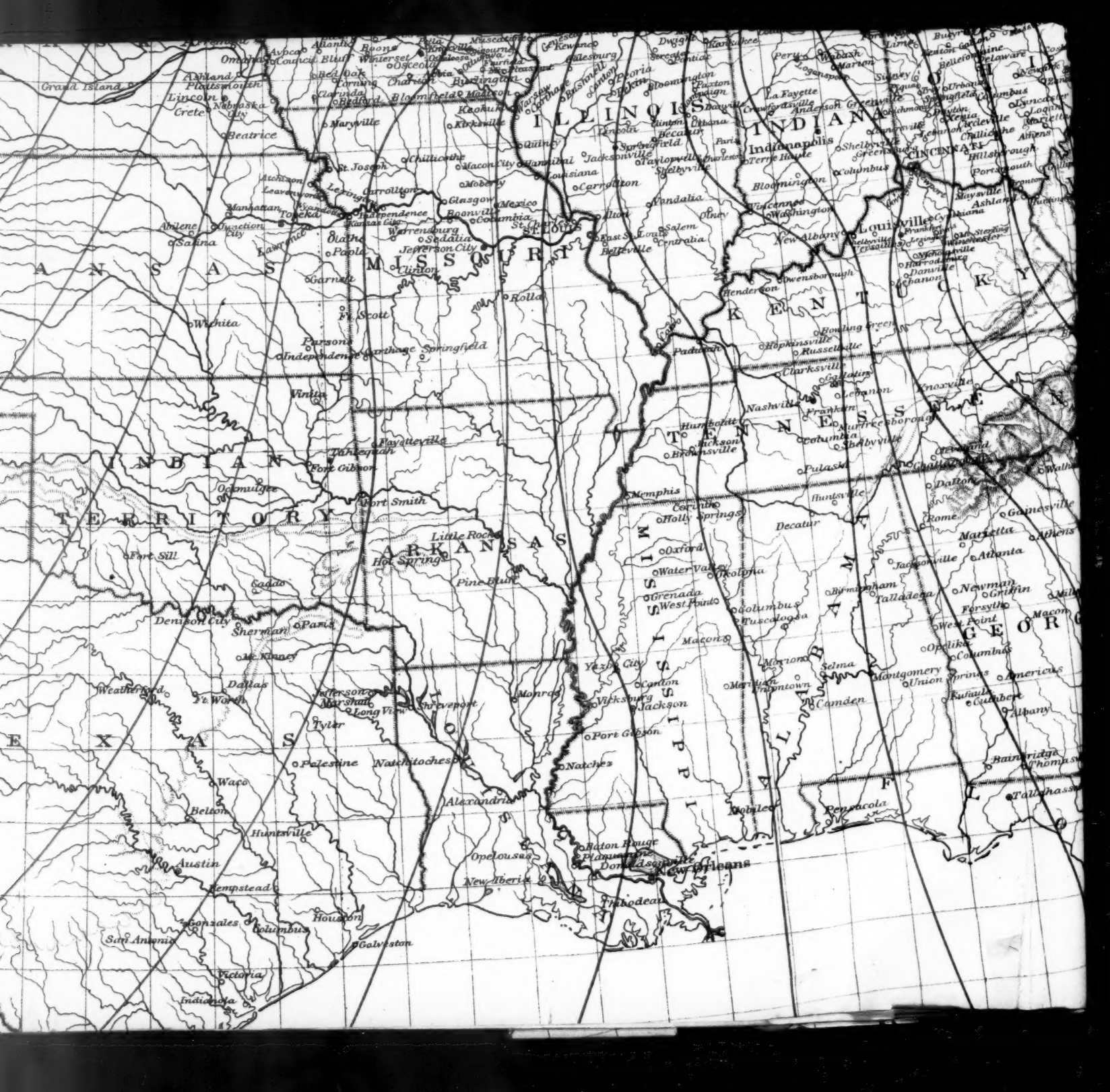
NEW MEXICO
LOWER CALIFORNIA
GULF OF CALIFORNIA


ILLINOIS
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Indianapolis
CINCINNATI
Louisville
Nashville
Memphis
Vicksburg
Jackson
Natchez
Mobile
New Orleans
Pensacola
Montgomery
Atlanta
Birmingham
Columbus
Selma
Decatur
Huntsville
Knoxville
Chattanooga
Dalton
Rome
Marietta
Athens
Gainesville
Jacksonville
Tallahassee
Albany
Americus
Macon
Griffin
Newman
Talladega
Tuscaloosa
Florence
Corinth
Holly Springs
Oxford
Grenada
West Point
Yazoo City
Canton
Monroe
Shreveport
Little Rock
Hot Spring
Fort Smith
Fayetteville
Van Buren
Fort Gibson
Pine Blur
Fort Scott
Springfield
Carthage
Rolla
Paducah
Hopkinsville
Russellville
Bowling Green
Clarksville
Lebanon
Murfreesboro
Shelbyville
Columbia
Franklin
Humboldt
Jackson
Brownsville
Pulaski
Wichita
Parsons
Independence
Vinita
Sherman
Denison City
Paris
Dallas
Ft Worth
Weatherford
Jefferson
Marshall
Long View
Tyler
Palestine
Waco
Belton
Austin
Hempstead
Houston
Galveston
Gonzales
Columbus
San Antonio
Victoria
Indianola
Alexandria
Natchitoches
Opelousas
New Iberia
Donaldsonville
Baton Rouge
Pranquemine
Thibodeaux
Port Gibson
Camden
Union Springs
Eufaula
Cuthbert
Bainbridge
Thomasville
Quincy
Hannibal
Louisiana
Carrollton
Glasgow
Mexico
Columbia
Boonville
Jefferson City
Sedalia
Warrensburg
Kansas City
Independence
Lexington
Carrollton
Chillicothe
Macon City
Moberly
St. Joseph
Atchison
Leavenworth
Manhattan
Topeka
Junction City
Abilene
Salina
Lawrence
Olathe
Paola
Garnett
Clinton
Wichita
Ashland
Plattsmouth
Grand Island
Lincoln
Nebraska City
Crete
Beatrice
Omaha
Council Bluff
Avoca
Atlantic
Boone
Winterset
Osceola
Red Oak
Corning
Clarinda
Bedford
Kirksville
Maryville
Kaokuk
Monticello
Bloomfield
Centerville
Chariton
Fairfield
Mount Pleasant
Burlington
Oquawka
Galesburg
Knoxville
Peoria
Lincoln
Bloomington
Pontiac
Decatur
Springfield
Jacksonville
Carrollton
Louisiana
Hannibal
Quincy
Macon City
Chillicothe
Kewanee
Dwight
Morris
Ottawa
Aurora
Sycamore
Elgin
Rockford
Freeport
Galena
Dubuque
Monticello
Lafayette
Crawfordsville
Terre Haute
Paris
Shelbyville
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Anderson
Richmond
Centreville
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Versailles
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Frankfort
Georgetown
Lexington
Harrodsburg
Danville
Shelbyville
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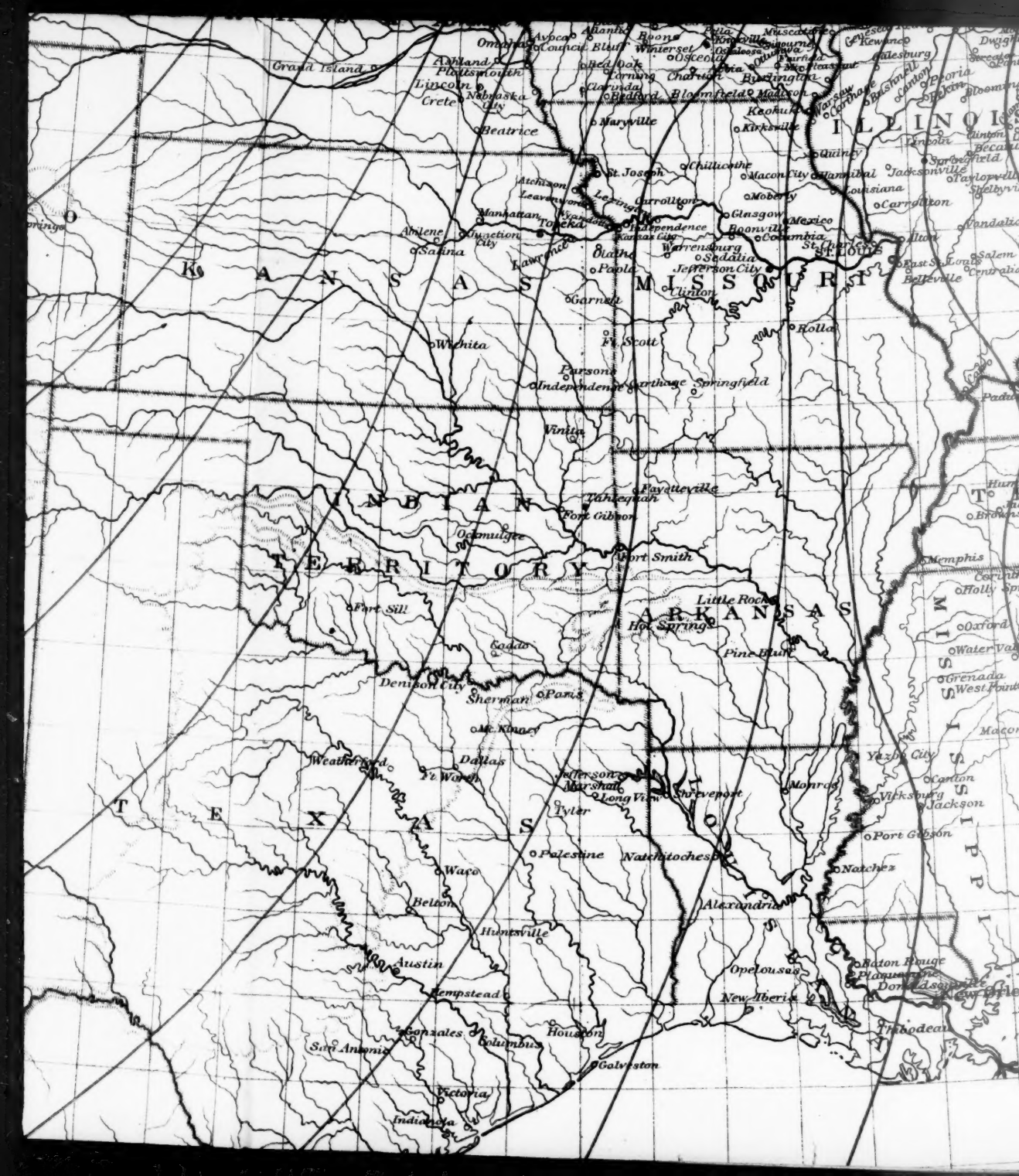
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Glasgow
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St. Louis
Lincoln
Crete
Nebraska City
Beatrice
Maryville
Kirksville
Macon City
Moberly
Chillicothe
St. Joseph
Atchison
Leavenworth
Lexington
Carrollton
Manhattan
Topeka
Wyandotte
Kansas City
Independence
Boonville
Abilene
Junction City
Salina
Lawrence
Olathe
Paola
Warrensburg
Sedalia
Jefferson City
Clinton
Garnett
Rolla
Wichita
Ft. Scott
Parsons
Independence
Carthage
Springfield
Vinita
Fayetteville
Tahlequah
Fort Gibson
Okmulgee
Fort Smith
Little Rock
Hot Springs
Pine Bluff
Memphis
Fort Sill
Cadde
Denison City
Sherman
Paris
Mc Kinney
Weatherford
Dallas
Ft Worth
Jefferson
Marshall
Long View
Shreveport
Monroe
Tyler
Palestine
Natchitoches
Waco
Belton
Huntsville
Austin
Hempstead
Alexandria
Opelousas
New Iberia
Baton Rouge
Natchez
Port Gibson
Vicksburg
Jackson
Yazoo City
Grenada
Oxford
Water Valley
West Point
Gonzales
Columbus
Houston
San Antonio
Galveston
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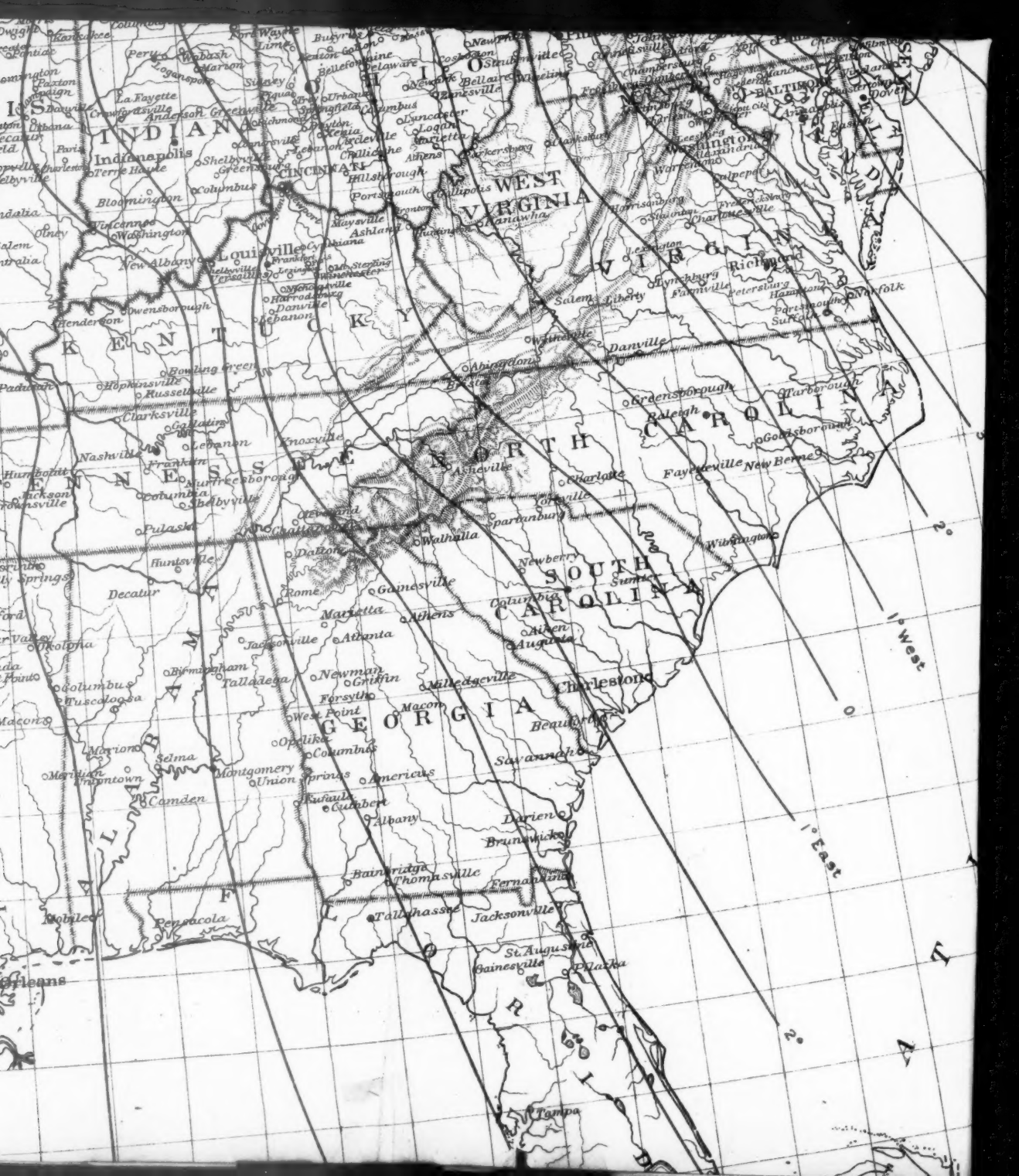
ILLINOIS
INDIAN TERRITORY
ARKANSAS
TEXAS
LOUISIANA
MISSISSIPPI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Columbus
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Vincennes
Washington
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Henderson
Hopkinsville
Bowling Green
Russellville
Clarksville
Nashville
Franklin
Columbia
Shelbyville
Pulaski
Huntsville
Decatur
Florence
Tuscaloosa
Birmingham
Talladega
Jacksonville
Atlanta
Rome
Marietta
Athens
Gainesville
Newman
Griffin
Milledgeville
Macon
Forsyth
West Point
Opelika
Columbus
Marion
Selma
Montgomery
Union Springs
Americus
Eufaula
Cuthbert
Albany
Camden
Mobile
Pensacola
Tallahassee
Bainbridge
Thomasville
Darien
Brunswick
Jacksonville
St. Augustine
Gainesville
Palatka
Tampa
Orleans
Lake
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Wheeling
Parkersburg
Charleston
Point Pleasant
Ashland
Maysville
Cincinnati
Hillsborough
Portsmouth
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Springfield
Dayton
Xenia
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Logan
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Cadiz
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Wheeling
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Hagerstown
Frederick
Baltimore
Annapolis
Easton
Dover
Philadelphia
Lancaster
Harrisburg
Chambersburg
Gettysburg
Hanover
York
Carlisle
Shippensburg
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Beaver
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Warren
Franklin
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Bellefonte
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Sunbury
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Allentown
Bethlehem
Doylestown
Norristown
Trenton
Princeton
Burlington
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Bridgeton
Cape May
Atlantic City
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Tuckerton
Barnegat
Toms River
Freehold
Elizabethtown
Newark
Jersey City
New York
Long Island
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Staten Island
Perth Amboy
New Brunswick
Somerville
Flemington
Easton
Phillipsburg
Belvidere
Hackettstown
Morristown
Paterson
Hackensack
Bergen
Newburgh
Poughkeepsie
Kingston
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Troy
Schenectady
Saratoga
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Syracuse
Auburn
Geneva
Canandaigua
Rochester
Batavia
Lockport
Buffalo
Niagara
Canada
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Oswego
Sackets Harbor
Watertown
Ogdensburgh
Potsdam
Plattsburgh
Lake Champlain
Burlington
Middlebury
Rutland
Bennington
Brattleboro
Windsor
Woodstock
Montpelier
Barre
Windsor
Hanover
Concord
Portsmouth
Dover
Exeter
Newburyport
Salem
Boston
Cambridge
Lowell
Worcester
Springfield
Northampton
Greenfield
Pittsfield
Lenox
Hartford
New Haven
Middletown
Norwich
New London
Stonington
Providence
Newport
Bristol
Taunton
Plymouth
Barnstable
Nantucket
Martha's Vineyard
Cape Cod
Cape Ann
Portland
Augusta
Hallowell
Waterville
Bangor
Machias
Eastport
Passamaquoddy Bay
Gulf of St. Lawrence
Anticosti
Gaspé
Bay of Chaleurs
Miramichi
Fredericton
St. John
Nova Scotia
Halifax
Cape Sable
Sable Island
Cape Breton
Prince Edward Island
Charlottetown
Pictou
Newfoundland
St. John's
Cape Race
Cape Ray
Cape Anguille
Cape Pine
Cape Bonavista
Cape St. Francis
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Cape Bonavista
Cape St. Mary
Placentia
Placentia Bay
Fortune Bay
Burin
Hermitage Bay
Connaigre Bay
Bay of Exploits
Notre Dame Bay
Twillingate
Fogo
Trinity Bay
Conception Bay
Carbonear
Harbour Grace
Bay de Verde
Labrador
Hudson's Strait
Cape Chidley
Resolution Island
Frobisher's Strait
Cape Mercy
Cape Wolstenholme
Hudson's Bay
Cape Henrietta Maria
Moose
Albany
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Fort George
Fort Nelson
Severn
Churchill
Fort Prince of Wales
Nelson
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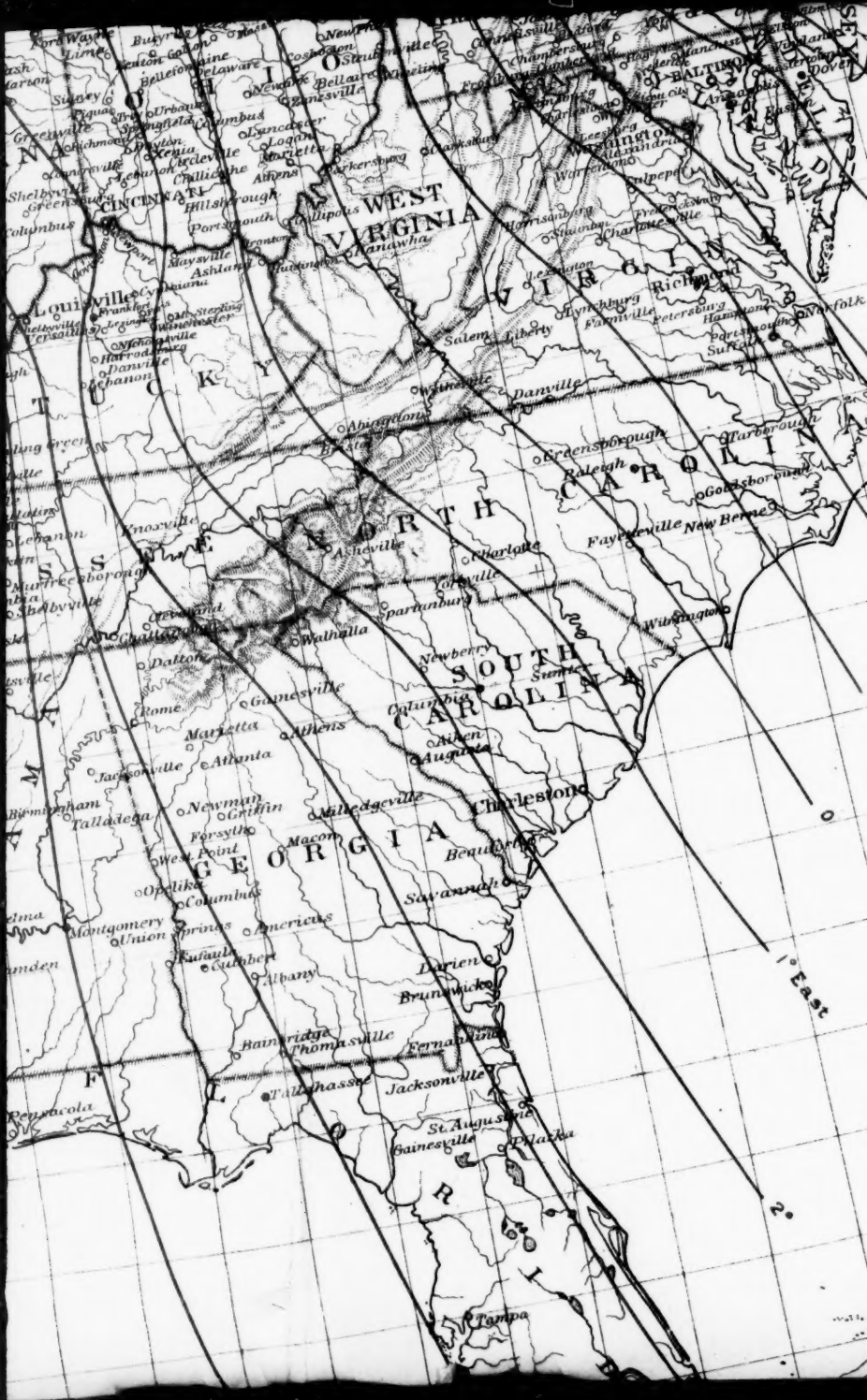
Fort York
Fort Bourbon
Fort Albany
Moose


WEST VIRGINIA
VIRGINIA
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Louisville
Richmond
Raleigh
Charleston
Savannah
Atlanta
Jacksonville
Tampa
Pensacola
Tallahassee
Montgomery
Columbus
Augusta
Athens
Asheville
Charlotte
Knoxville
Nashville
Wilmington
New Berne
Fayetteville
Danville
Salem
Lynchburg
Petersburg
Norfolk
Baltimore
Washington
Harrisburg
Pittsburgh
Wheeling
Parkersburg
Huntington
Lexington
Frankfort
Cincinnati
Columbus
Dayton
Springfield
Zanesville
Marietta
Athens
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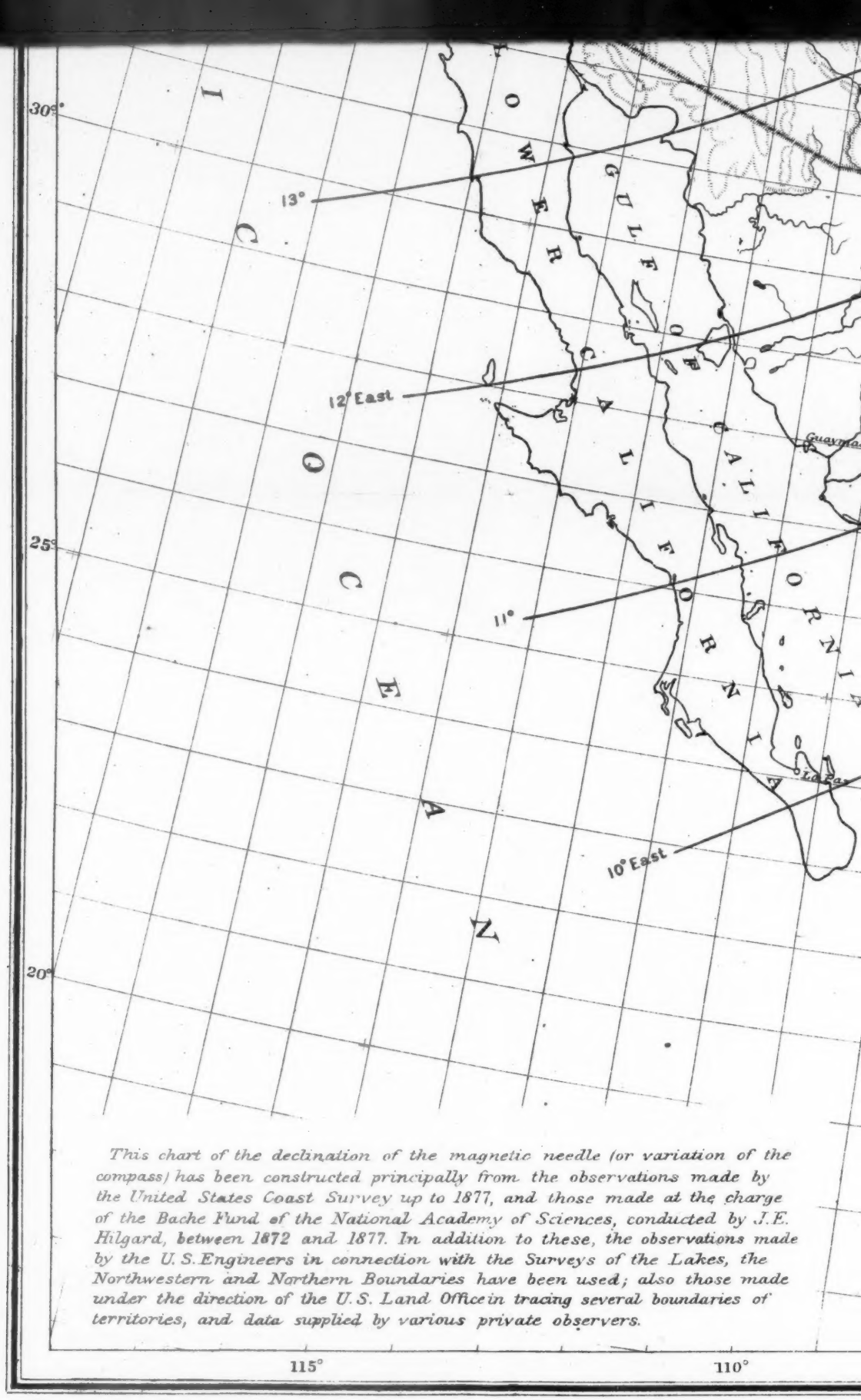
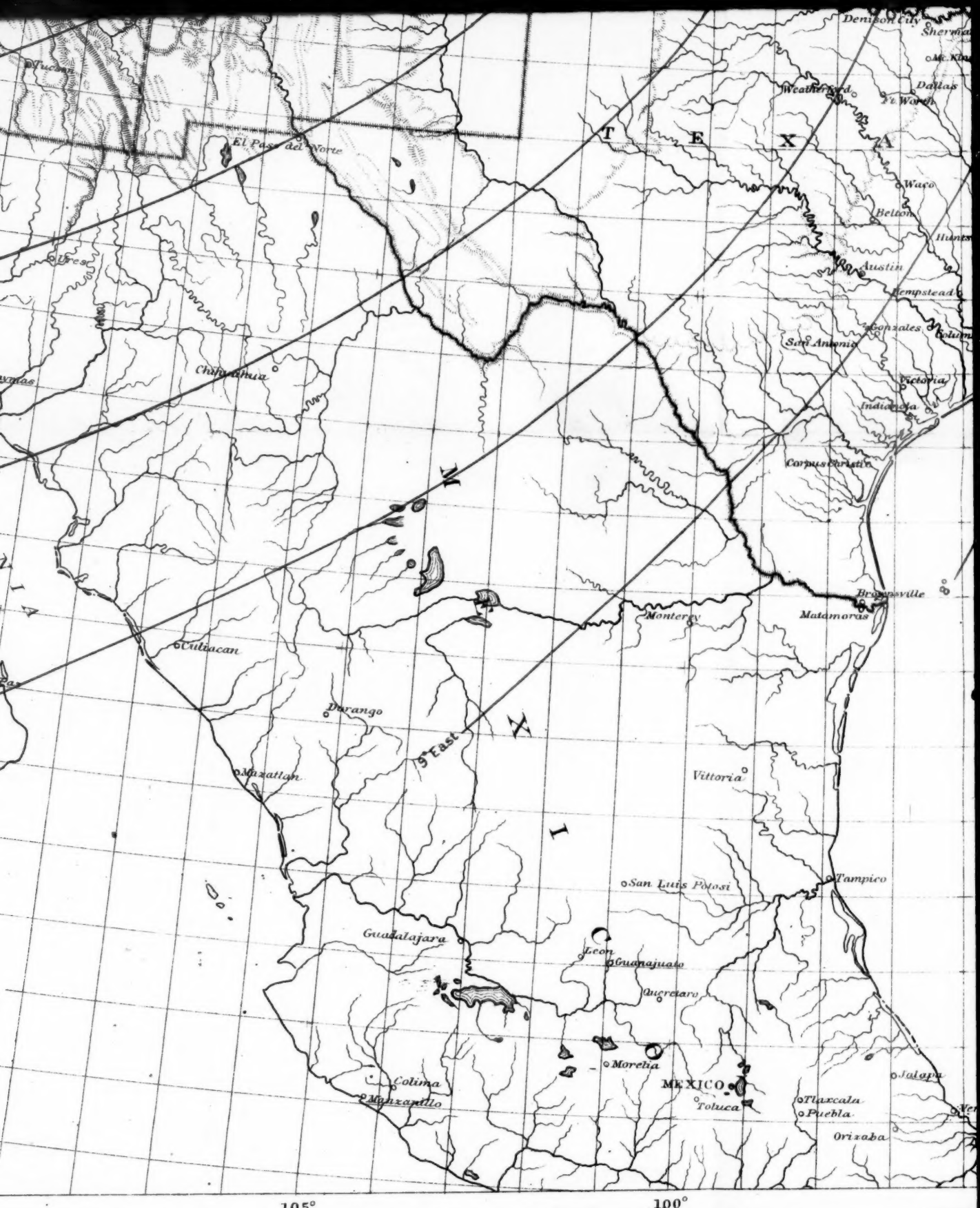
Chillicothe
Portsmouth
Maysville
Ashland
Huntington
Greenville
Spartanburg
Columbia
Newberry
Sumter
Camden
Augusta
Aiken
Charleston
Beaufort
Savannah
Darien
Brunswick
Jacksonville
St. Augustine
Palatka
Gainesville
Ocala
Tampa
Macon
Milledgeville
Griffin
Newman
Talladega
Birmingham
Rome
Dalton
Chattanooga
Walhalla
Greenville
Abbeville
Edenton
Tarborough
Goldsborough
Wilmington
1° East
2°

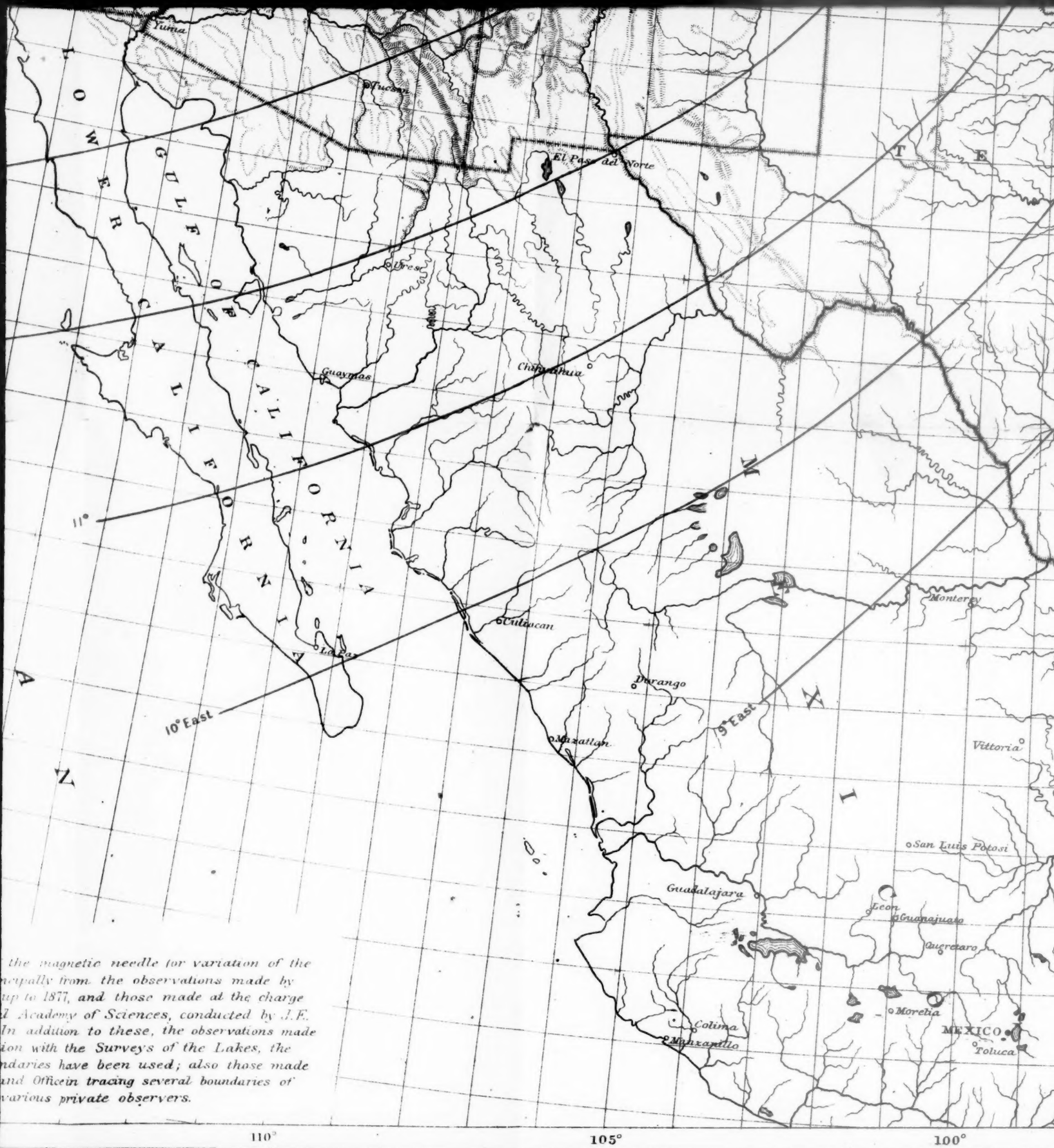
7°
6°
5°
4° West
3°
2°
1° West
35°
30°
A T L A N T I C O C E A N
Norfolk



This chart of the declination of the magnetic needle (or variation of the compass) has been constructed principally from the observations made by the United States Coast Survey up to 1877, and those made at the charge of the Bache Fund of the National Academy of Sciences, conducted by J.E. Hilgard, between 1872 and 1877. In addition to these, the observations made by the U.S. Engineers in connection with the Surveys of the Lakes, the Northwestern and Northern Boundaries have been used; also those made under the direction of the U.S. Land Office in tracing several boundaries of territories, and data supplied by various private observers.



Drawn and engraved by A



the magnetic needle for variation of the
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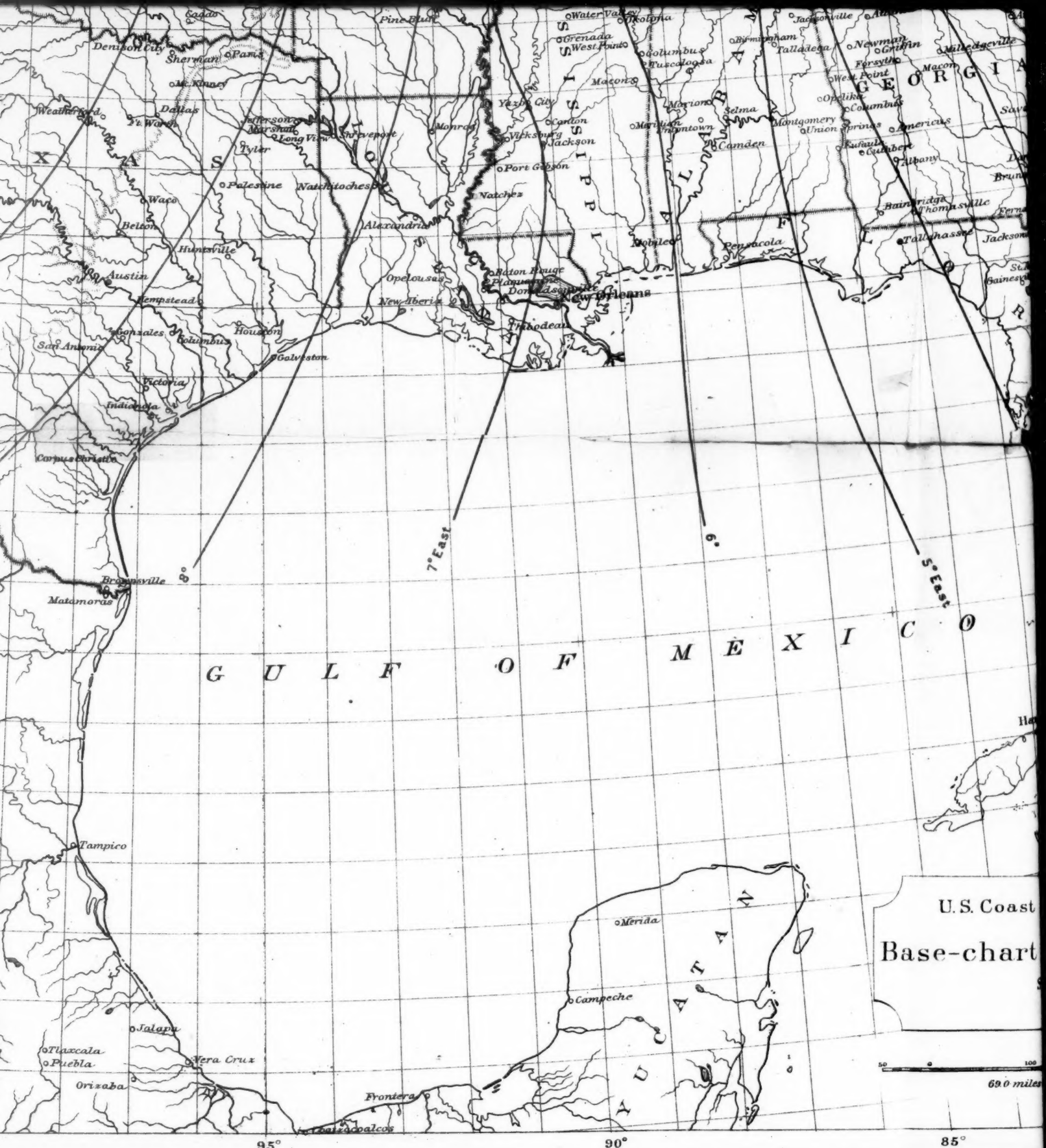
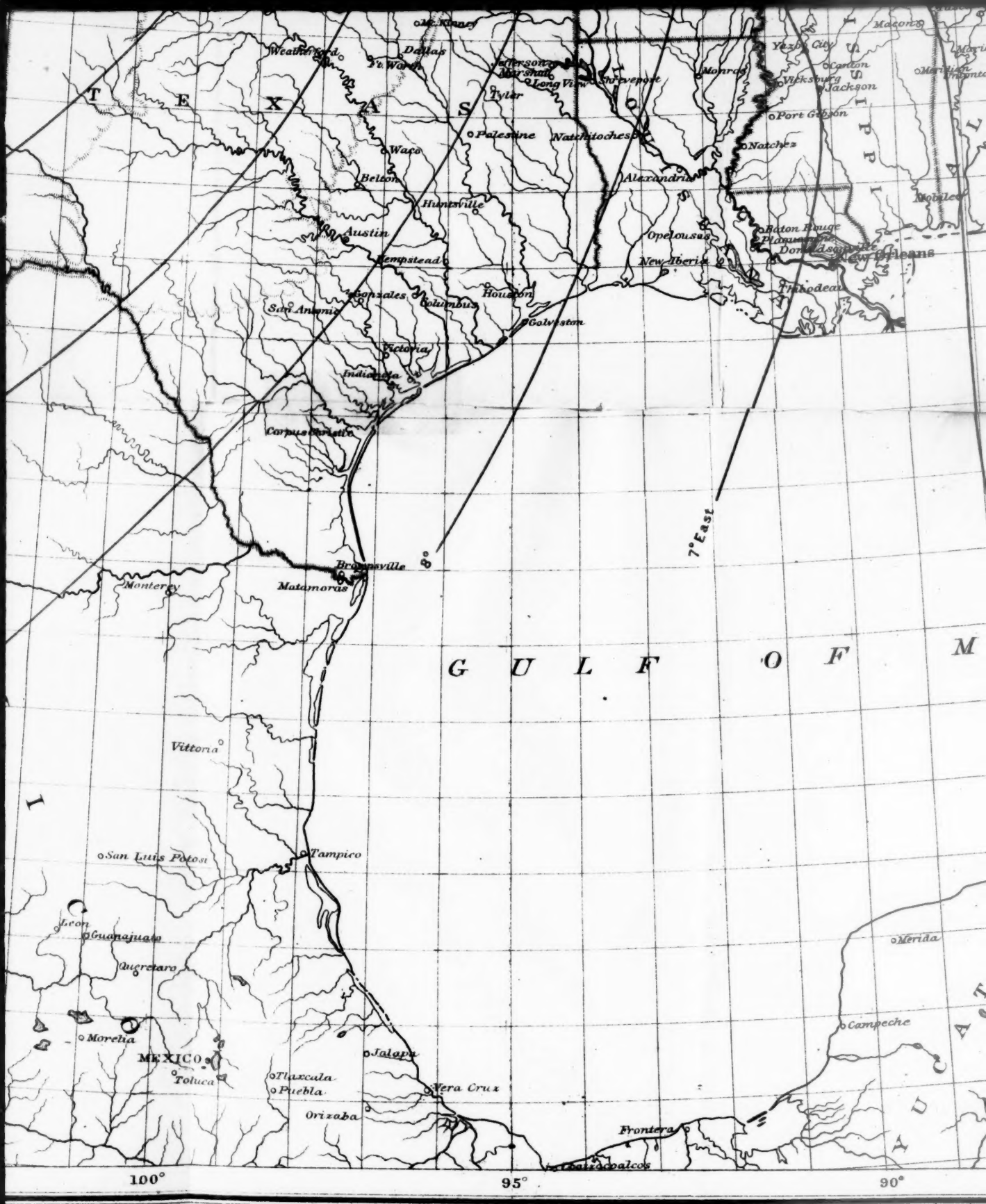


Drawn and engraved by A and H. Lindenkohl.



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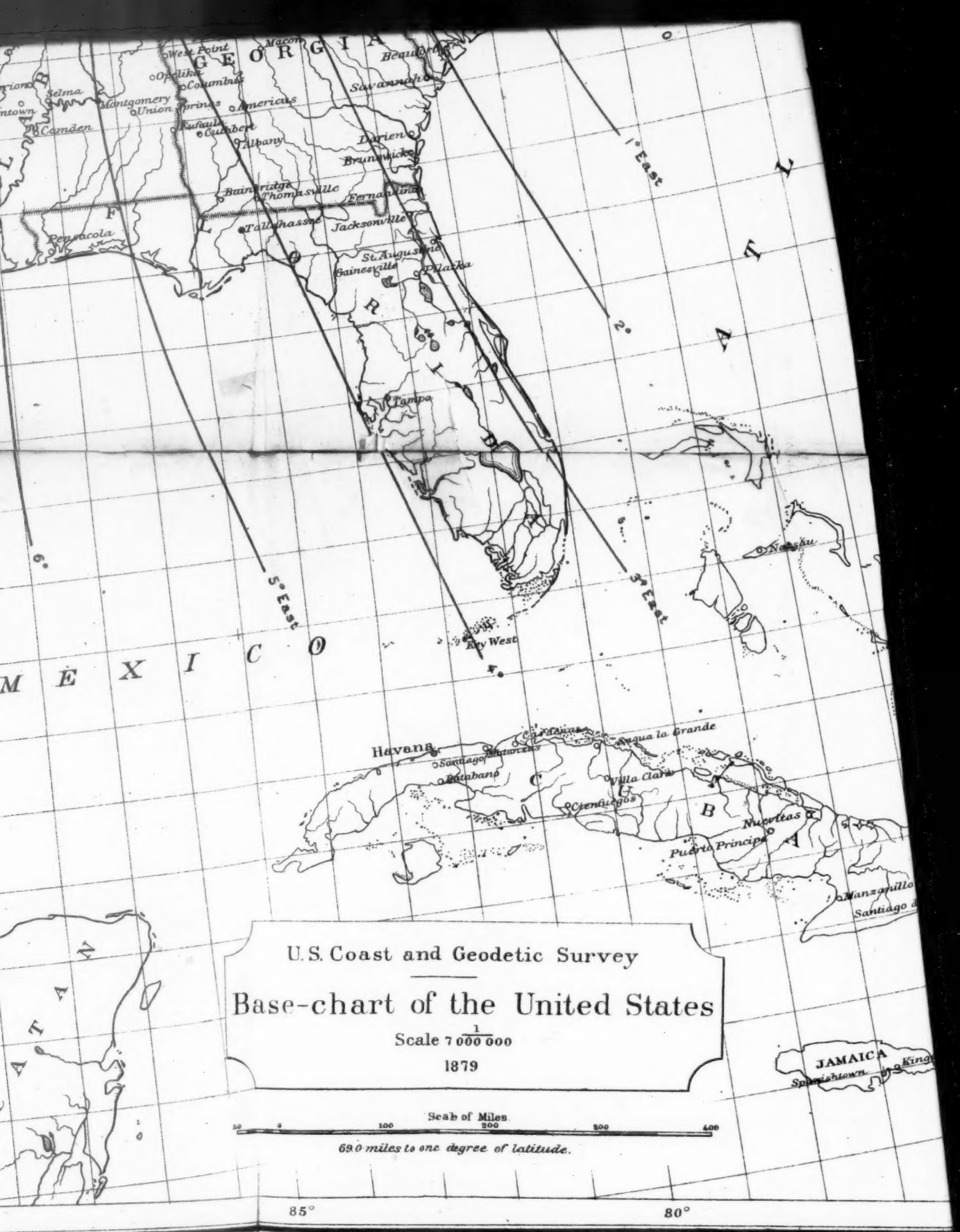


U.S. Coast and Geodetic Survey

Base-chart of the United States

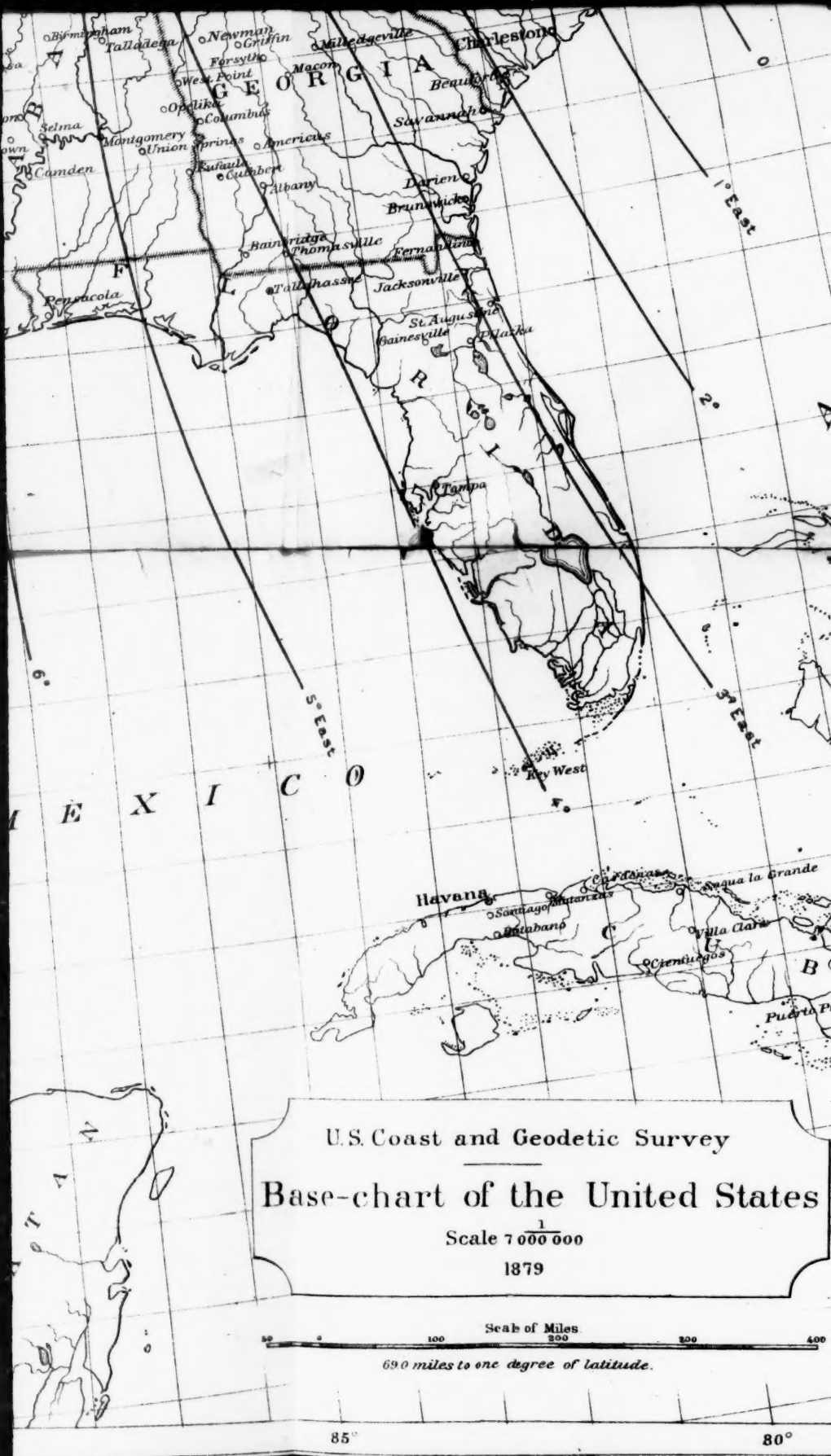
Scale $7\frac{1}{000\,000}$

1879

Scale of Miles

0 100 200 300 400

69.0 miles to one degree of latitude.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Newman
Griffin
Forsyth
Milledgeville
Charleston
Macon
West Point
GEORGIA
Beaufort
Opelika
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Savannah
Selma
Montgomery
Union Springs
Americus
Camden
Eufaula
Cuthbert
Albany
Darien
Brunswick
Bainbridge
Thomasville
Fernandina
Tallahassee
Jacksonville
Pensacola
St. Augustine
Gainesville
Palatka
Tampa
Key West
Havana
Matanzas
Cardenas
Sagua la Grande
Santiago
Batabano
Villa Clara
Cienfuegos
Puerto P
1° East
2°
3° East
5° East
9°
M E X I C O
U.S. Coast and Geodetic Survey
Base-chart of the United States
Scale 1/7 000 000
1879
Scale of Miles
50 0 100 200 300 400
69.0 miles to one degree of latitude.
85°
80°

30°

25°

Nassau

Nuevitas

Manzanillo

Santiago de Cuba

20°

JAMAICA

Spanishtown

Kingston

75°

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XXII.—*On a Chart of the Magnetic Declination in the United States, constructed, by* J. E. HILGARD, Assistant U. S. Coast and Geodetic Survey. With Plate V.

[From the United States Coast Survey Report for 1876.]

SIR: I submit to you herewith, for publication in the Coast Survey Report for 1876, a chart of the magnetic variation in the United States. This chart, which shows the lines of equal magnetic declination (so-called Isogonic lines) for the year 1875, is mainly based upon the observations made during the progress of the coast survey up to 1877, together with those made under my personal direction during the period 1872–'77, at the charge of the fund bequeathed for scientific research by the late Professor Alexander Dallas Bache, held in trust by the National Academy of Sciences.

When the income of this fund became available for its objects, I proposed, in 1871, to the board of direction, then consisting of Professors Joseph Henry, Louis Agassiz, and Benjamin Peirce, that a portion of it should be devoted to the investigation of terrestrial magnetism in the United States, that subject being one in which Professor Bache had taken much interest, and in the investigation of which he had been personally engaged. Moreover, while this was a subject of general importance, there was not at that time any provision made for its prosecution on the part of the government. The board of direction having approved of my proposition, an allotment was made for several years in succession, and the observations were prosecuted under my immediate direction by observers whom